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Geostrophic Transport Estimates from the Canadian Arctic Archipelago

by

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ABSTRACT

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Geostrophic current fields that are perpendicular to water property measurement transects were derived from conductivity, temperature, and depth (CTD) data measured in Barrow Strait, Wellington Channel, and Lancaster Sound in the Canadian Arctic Archipelago. The objective was to provide a snapshot of the spatial variation of the transport through these sections at the time of the profiles. These derived current fields are useful in properly assessing estimates of total transport computed from data measured by current profilers in the late 1990's.

RÉSUMÉ

van der Baaren, A. and S. J. Prinsenberg. 2002. Geostrophic Transport Estimates from the Canadian Arctic Archipelago. *Can. Tech. Rep. Hydrogr. Ocean Sci. 220*: ix + 66 p.

On a déterminé les champs de courants géostrophiques, perpendiculaires aux transects de mesure des propriétés de l'eau, d'après les données de conductivité, température et profondeur (CTP) mesurées dans le détroit de Barrow, le chenal Wellington et le détroit de Lancaster, dans l'archipel Arctique. Le but était de connaître la variation spatiale du transport dans ces transects lors de l'établissement des profils. Ces champs de courant dérivés sont utiles pour bien évaluer les estimations totales de transport calculées d'après les données mesurées par les sondeurs de profils de courant à la fin des années 1990.

1 INTRODUCTION

Renewed interest in the Canadian high Arctic prompted recent field studies of the Barrow Strait region in the Canadian Arctic Archipelago. These surveys included extended measurement of currents and water temperature and conductivity with respect to depth to give an overall picture of physical oceanographic conditions in the area. In the early 1980's a more extensive regional winter survey was conducted, and, although the data were analyzed and reported, the analysis did not include geostrophic calculations. This report describes geostrophic velocity estimates derived from CTD data that were measured in the 1980's and fifteen years later in the late 1990's. The purpose was to compare the results seasonally and interannually. Summer estimates would also help determine future mooring configurations for Lancaster Sound.

Geostrophic velocity calculations assume that density gradients derived from salinity and temperature fields vary much less in the along-strait direction than in the cross-strait direction. This assumption is required in order to have the observed cross-strait gradients be independent of the varying high-frequency currents over the time period that the CTD profiles were taken, which, hopefully depend on long period currents. In late winter when the ice reaches its maximum thickness this condition is generally met. However, during the short summer local runoff, local ice melt, and variation in the net heat flux into the ocean (due to variable ice cover extent) cause large local variations in density that have not adjusted to geostrophic conditions. The other assumption is the zero reference level at the bottom contour; it assumes that the relative velocity field due to baroclinicity can be inferred as an absolute velocity field. This is an approximation that may or may not be valid, especially in this shallow strait close to shore. Limitations on using the geostrophic method for computing current velocities is discussed in Pond and Pickard (1983, pp. 93-95).

This short report describes the process of obtaining the estimates for geostrophic velocity and transport in three Barrow Strait cross-sections for CTD profiles taken in the 1980's and 1990's. The main body of the report contains descriptions of data and the computational process as well as listing selected results in tables and graphically. The appendix contains plots of contoured data cross-sections and computed relative velocities.

2 DATA

In the early 1980's and in the late 1990's, CTD (conductivity, temperature, and depth) data were recorded in the Canadian Arctic Archipelago in extensive summer and winter surveys. The fieldwork for the 1980's encompassed the entire region whereas the sampling in the 1990's focussed only on Barrow Strait, Lancaster Sound, and Wellington Channel. CTD data for 1918, 1982, and 1983 were published in data reports (Prinsenberg and Sosnoski, 1983a, 1983b, 1983c) and an analysis of mixing and transport using these data and current meter data were published as a scientific manuscript (Prinsenberg and Bennett, 1987). Data were available for the following years: 1981, 1982, 1983, 1998, 1999, and 2000. Transects were selected that crossed Barrow Strait (west Barrow), western Lancaster Sound (east Barrow), and southern Wellington Channel (north Barrow) (Figure 1 and Figure 2).

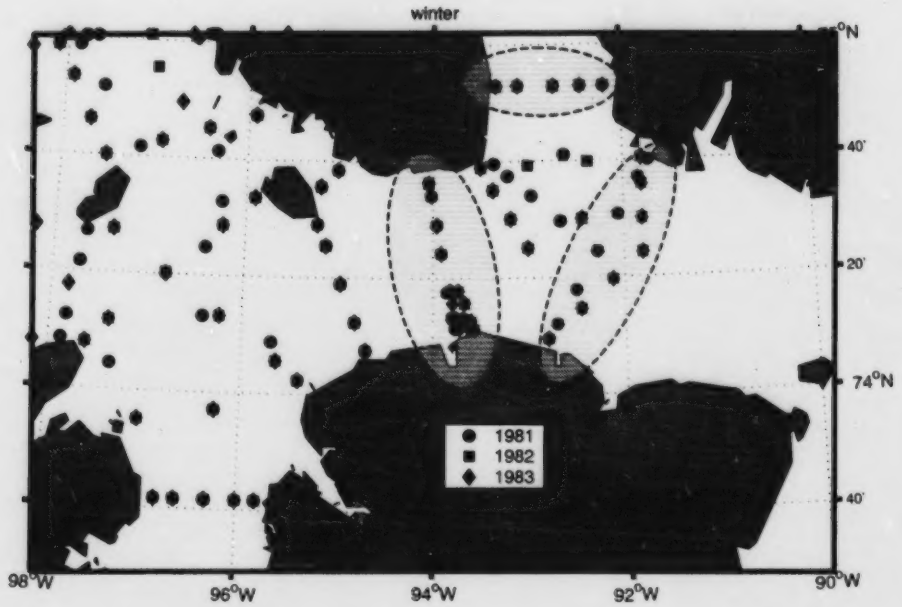

Figure 1 Map of winter CTD stations for Barrow Strait (1981-1983) highlighting western, eastern, and northern transects.

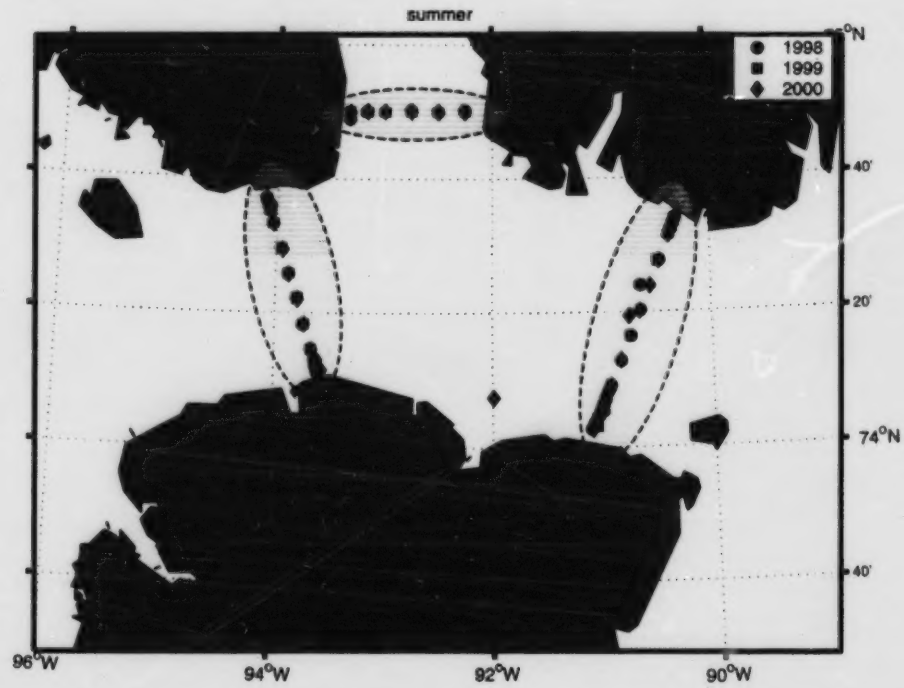

Figure 2 Map of summer CTD stations for Barrow Strait (1998-2000) highlighting western, eastern, and northern transects.

Data for 1981, 1982, and 1983 were collected in April (winter). Data for the other years were collected in August (summer). Some transects were performed more than once for a given year. The different days and years are listed in Table 1.

Table 1 List of field years and calendar days of CTD sampling in Barrow Strait.

	Summer		
Year	West	East	North
1998	Day 226	Day 223, 224	Day 225
1999	232	233	231
2000	222, 223	219, 220, 221	224, 225
	Winter		
	West	East	North
1981	Day 108	Day 110	Day 115
1982	86, 88, 94,112	90, 111	97
1983	92, 94, 112	98	111

Personnel from the Bayfield Laboratory performed sampling in the 1980's for Marine Science and Surveys in Burlington, Ontario using helicopter support from the Polar Continental Shelf Project. Instrumentation consisted of a Guildline Mark IV CTD probe, deck unit, and TEAC PC-10 cassette tape recorder. Data were initially processed in the field and later reported in the data reports produced internally in Burlington. During the ensuing years, the magnetic tapes of the processed data were lost and digital records were reproduced by manual entry from the internal reports with some loss in precision.

Sampling in the 1990's and in 2000 was performed by personnel from the Bedford Institute of Oceanography in Dartmouth, Nova Scotia supported by icebreakers from the Canadian Coast Guard. Instrumentation consisted of a Seabird SBE-25 CTD probe.

The profile times for the data used in the geostrophic computations are listed in the following table.

Table 2 Profile times for CTD stations.

YEAR	TRANSECT	STATION	LOCATION	TIME	MAX DEPTH (SOUNDING)
1981	EAST	61	74.6650; -91.7200	20 APR 19:58	111.0 m
		62	74.6167; -91.8333	20 APR 19:15	180.0 m
		63	74.5117; -92.0550	20 APR 18:45	280.1 m
		64	74.4067; -92.2750	20 APR 17:34	278.0 m
		65	74.2967; -92.5000	20 APR 17:03	175.0 m
		66	74.2000; -92.7000	20 APR 16:33	161.4 m
		67	74.1583; -92.7917	20 APR 15:44	118.3 m
	WEST	41	74.6033; -94.0467	18 APR 14:42	88.0 m
		42	74.5667; -94.0183	18 APR 15:21	126.0 m
		43	74.4833; -93.9583	18 APR 15:49	152.0 m
		44	74.4017; -93.9117	18 APR 16:16	146.0 m
		45	74.2917; -93.8500	18 APR 16:45	158.0 m
		46	74.2217; -93.7967	18 APR 17:23	167.0 m
		47	74.1883; -93.7650	18 APR 17:48	38.0 m
	NORTH	91	74.8800; -93.3300	25 APR 22:45	136.0 m
		92	74.8800; -93.1000	25 APR 22:10	184.0 m
		93	74.8800; -92.7167	25 APR 21:39	130.2 m
		94	74.8800; -92.4300	25 APR 21:06	141.5 m
		95	74.8800; -92.1833	25 APR 20:32	86.0 m
1982	EAST	61	74.6720; -91.8000	31 MAR 14:49	118.0 m
		62	74.5970; -91.8000	31 MAR 15:24	133.0 m
		63	74.5000; -91.8000	31 MAR 15:55	148.0 m
		64	74.4030; -91.8000	31 MAR 16:27	248.0 m
		65	74.3270; -92.1170	31 MAR 16:56	284.0 m
		66	74.2430; -92.4500	31 MAR 17:32	174.0 m
		67	74.1580; -92.7920	31 MAR 19:15	138.0 m
	WEST	40	74.1840; -93.6010	27 MAR 15:03	20.0 m
		41	74.6030; -94.0470	22 APR 18:58	98.0 m
		42	74.5670; -94.0180	22 APR 18:36	132.0 m
		43	74.4830; -93.9580	22 APR 18:09	146.0 m
		44	74.4020; -93.9120	22 APR 17:25	170.0 m
		45	74.2950; -93.7330	22 APR 16:40	163.0 m
		46	74.2180; -93.6850	22 APR 15:36	168.0 m
		47	74.1880; -93.5650	22 APR 14:36	56.0 m
		48	74.2100; -93.6000	22 APR 15:12	150.0 m
		49	74.2600; -93.6670	22 APR 16:03	180.0 m

YEAR	TRANSECT	STATION	LOCATION	TIME	MAX DEPTH (SOUNDING)
1982	NORTH	91	74.8800; -93.3330	07 APR 17:58	206.0 m
		92	74.8800; -93.1000	07 APR 17:29	162.0 m
		93	74.8800; -92.7170	07 APR 17:05	144.0 m
		94	74.8800; -92.4300	07 APR 16:31	148.0 m
		95	74.8800; -92.1830	07 APR 16:06	72.0 m
1983	EAST	61	74.6720; -91.8000	08 APR 18:22	137.0 m
		62	74.5970; -91.8000	08 APR 18:58	136.0 m
		63	74.5000; -91.8000	08 APR 19:35	172.0 m
		64	74.4030; -91.8000	08 APR 16:34	309.0 m
		65	74.3270; -92.1170	08 APR 15:56	184.0 m
		66	74.2430; -92.4500	08 APR 15:19	173.0 m
		67	74.1580; -92.7920	08 APR 14:42	140.0 m
	WEST	41	74.6030; -94.0470	22 APR 14:18	92.0 m
		42	74.5670; -94.0180	22 APR 14:50	134.0 m
		43	74.4830; -93.9580	22 APR 15:23	146.0 m
		44	74.4020; -93.9120	22 APR 15:54	156.0 m
		45	74.2950; -93.8170	22 APR 16:34	167.0 m
		46	74.2180; -93.7580	22 APR 17:39	160.0 m
		47	74.1880; -93.7170	22 APR 19:28	80.0 m
		48	74.2100; -93.7330	22 APR 19:58	153.0 m
		49	74.2600; -93.7920	22 APR 17:07	177.0 m
	NORTH	91	74.8800; -93.3330	21 APR 17:17	173.0 m
		92	74.8800; -93.1000	21 APR 16:44	152.0 m
		93	74.8800; -92.7170	21 APR 16:10	126.5 m
		94	74.8800; -92.4300	21 APR 15:40	133.0 m
		95	74.8800; -92.1830	21 APR 15:04	66.0 m
1998	EAST	2	74.0591; -91.0845	11 AUG 05:12	98.0 m
		3	74.0754; -91.0522	11 AUG 05:37	139.0 m
		4	74.0881; -91.0097	11 AUG 06:05	158.0 m
		5	74.1062; -91.0065	11 AUG 06:40	179.0 m
		6	74.1219; -90.9851	11 AUG 07:07	193.0 m
		7	74.1378; -90.9613	11 AUG 07:29	211.0 m
		8	74.1524; -90.9362	11 AUG 07:52	222.0 m
		9	74.2130; -90.8416	12 AUG 23:32	280.0 m
		10	74.2735; -90.7470	12 AUG 22:55	238.0 m
		11	74.3369; -90.6542	12 AUG 22:17	218.0 m
		12	74.3992; -90.6515	12 AUG 21:30	203.0 m
		13	74.4612; -90.4686	12 AUG 20:10	280.0 m
		14	74.5224; -90.3758	12 AUG 14:08	223.0 m
		15	74.5365; -90.3512	12 AUG 13:33	196.0 m
		16	74.5518; -90.3281	12 AUG 13:03	166.0 m
		17	74.5666; -90.3096	12 AUG 12:29	101.0 m

YEAR	TRANSECT	STATION	LOCATION	TIME	MAX DEPTH (SOUNDING)
1998	WEST	24	74.1865; -93.6010	14 AUG 12:06	59.0 m
		25	74.2027; -93.6180	14 AUG 12:26	131.0 m
		26	74.2182; -93.6285	14 AUG 12:50	160.0 m
		27	74.2426; -93.6621	14 AUG 13:22	172.0 m
		28	74.3044; -93.7412	14 AUG 14:09	170.0 m
		29	74.3704; -93.8004	14 AUG 14:47	165.0 m
		30	74.4305; -93.8823	14 AUG 15:30	150.0 m
		31	74.4925; -93.9499	14 AUG 17:00	147.0 m
		32	74.5552; -94.0324	14 AUG 17:46	137.0 m
		33	74.5875; -94.0648	14 AUG 18:17	118.0 m
		34	74.6021; -94.0799	14 AUG 18:39	91.0 m
		35	74.6167; -94.1004	14 AUG 18:58	73.0 m
	NORTH	18	74.8370; -92.2514	13 AUG 12:11	96.0 m
		19	74.8335; -92.4994	13 AUG 13:00	124.0 m
		20	74.8358; -92.7546	13 AUG 13:42	134.0 m
		21	74.8334; -93.0013	13 AUG 14:48	152.0 m
		22	74.8331; -93.1737	13 AUG 15:46	176.0 m
		23	74.8149; -93.3319	13 AUG 17:12	138.0 m
1999	EAST	2	74.0501; -91.0646	21 AUG 12:21	72.0 m
		4	74.0911; -91.0283	21 AUG 11:15	156.0 m
		6	74.1215; -90.9845	21 AUG 10:46	194.0 m
		8	74.1515; -90.9373	21 AUG 10:14	220.0 m
		10	74.2745; -90.7525	21 AUG 23:09	235.0 m
		13	74.4596; -90.4850	21 AUG 21:32	277.0 m
		14	74.5233; -90.3760	21 AUG 20:23	221.0 m
		15	74.5391; -90.3515	21 AUG 19:57	194.0 m
		16	74.5536; -90.3283	21 AUG 19:28	154.0 m
		17	74.5663; -90.3083	21 AUG 19:10	83.0 m
	WEST	24	74.1866; -93.5983	20 AUG 20:47	60.0 m
		25	74.2016; -93.6158	20 AUG 20:28	129.0 m
		26	74.2170; -93.6303	20 AUG 20:12	160.0 m
		27	74.2433; -93.6650	20 AUG 19:43	175.0 m
		28	74.3048; -93.7313	20 AUG 19:09	170.0 m
		29	74.3700; -93.7993	20 AUG 18:29	163.0 m
		30	74.4298; -93.8790	20 AUG 17:54	150.0 m
		31	74.4916; -93.9505	20 AUG 17:16	148.0 m
		32	74.5541; -94.0325	20 AUG 16:38	136.0 m
		33	74.5860; -94.0675	20 AUG 15:40	119.0 m
		34	74.6016; -94.0845	20 AUG 15:04	91.0 m
		35	74.6001; -94.1010	20 AUG 14:44	76.0 m
	NORTH	18	74.8326; -92.2483	19 AUG 23:37	92.0 m
		19	74.8336; -92.4991	19 AUG 23:05	124.0 m
		20	74.8338; -92.7499	19 AUG 22:30	133.0 m
		21	74.8328; -92.9965	19 AUG 21:54	150.0 m
		22	74.8330; -93.1666	19 AUG 20:05	178.0 m
		23	74.8341; -93.3326	19 AUG 19:34	138.0 m

YEAR	TRANSECT	STATION	LOCATION	TIME	MAX DEPTH (SOUNDING)
2000	EAST	1	74.0437; -91.1012	06 AUG 14:19	51.0 m
		2	74.5933; -91.0800	06 AUG 15:12	97.5 m
		3	74.0742; -91.0575	06 AUG 16:09	127.5 m
		4	74.0897; -91.0316	06 AUG 17:42	154.0 m
		5	74.1039; -91.0122	06 AUG 18:08	178.0 m
		7	74.1369; -90.9573	06 AUG 20:07	209.0 m
		8	74.1517; -90.9350	06 AUG 21:01	223.0 m
		9	74.2150; -90.8417	06 AUG 22:33	283.0 m
		10	74.3234; -90.7576	06 AUG 23:26	234.0 m
		11	74.3358; -90.6627	07 AUG 00:11	214.0 m
		12	74.3977; -90.5630	08 AUG 13:19	203.0 m
		13	74.4595; -90.4735	08 AUG 14:15	279.0 m
		14	74.5225; -90.3820	08 AUG 15:29	226.0 m
		15	74.5373; -90.3578	08 AUG 15:50	192.0 m
		16	74.5528; -90.3327	08 AUG 16:19	152.0 m
		17	74.5660; -90.3132	08 AUG 17:47	86.0 m
	WEST	24	74.1915; -93.5675	10 AUG 23:24	76.0 m
		25	74.2017; -93.6056	10 AUG 23:06	129.0 m
		26	74.2169; -93.6116	10 AUG 22:39	159.0 m
		27	74.2426; -93.6590	10 AUG 21:21	173.0 m
		28	74.3046; -93.7277	10 AUG 20:44	172.0 m
		29	74.3657; -93.7951	10 AUG 19:56	161.0 m
		30	74.4289; -93.8786	10 AUG 19:02	150.0 m
		31	74.4890; -93.9376	10 AUG 18:22	149.0 m
		32	74.5543; -94.0277	10 AUG 17:40	139.0 m
		33	74.5865; -94.0597	10 AUG 16:23	121.0 m
		34	74.6009; -94.0571	09 AUG 17:48	94.0 m
		35	74.6140; -94.0937	09 AUG 15:37	72.0 m
	NORTH	18	74.8318; -92.2479	11 AUG 13:42	90.0 m
		19	74.8323; -92.4944	11 AUG 14:14	125.0 m
		20	74.8335; -92.7488	11 AUG 15:29	133.0 m
		21	74.8340; -93.0013	11 AUG 16:04	150.0 m
		22	74.8338; -93.1654	11 AUG 23:30	177.0 m
		23	74.8317; -93.3274	12 AUG 00:11	139.0 m

3 COMPUTATIONS

Measured temperature and salinity data were organized into 5 m vertical intervals for each straight-line transect using the resident optimal linear estimation (OAX) software at the Bedford Institute of Oceanography. The program uses nearest neighbours to provide least squares estimates from weighted averages of a specified number of points. Each transect required the choice of correlation scales associated with the independent variables that would minimize the size of the error. The acceptable error threshold was chosen to be 0.1 in all cases. The choice of the global scales varied geographically but not yearly. A brief explanation of the correlation scales can be found in the appendix of Loder, et al (1997). In some cases, although the acceptable level of error was attained, it was decided that the estimated density field was so unrealistic that larger scales were

chosen that would use more data points in the estimation. This seemed to better reflect a "true" picture regardless of the computational noise. In these cases the noise level was never more than 50% above the set threshold.

The least squares estimates (OAX estimates) of the April 22, 1982 CTD data for selected stations in Barrow Strait (east) were compared visually with the actual measured data (Figure 3, Figure 4, and Figure 5). The data were estimated to 200 m for the western transect which was chosen since the density field and geostrophic velocities could be compared with those pictured and described in Prinsenberg and Bennett. The comparison was repeated for April 1983 whereby both years' estimates compared favourably. It was noted that contoured axial velocities shown in Prinsenberg and Bennett (1987, Figures 10 and 11) were drawn from current meter data and are not representative of the estimates made from dynamic height calculations. Nevertheless, the text states: "Eastward currents were observed everywhere and they generally decreased with depth as indicated by dynamic height calculations." (Prinsenberg and Bennett, 1987, p. 923).

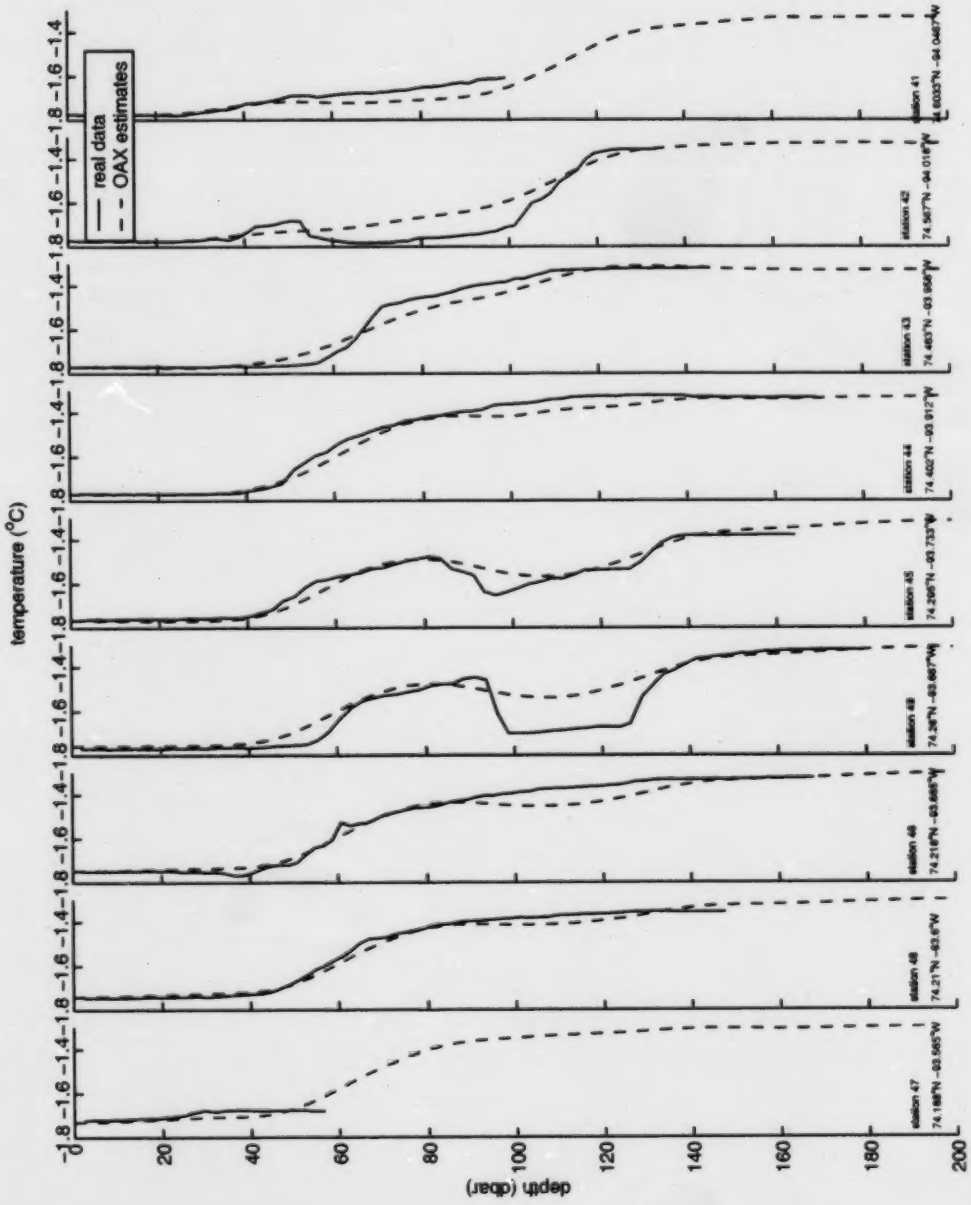

Figure 3 Profiles of April 22, 1982 CTD temperature measurements with OAX estimates for western Barrow Strait transect.

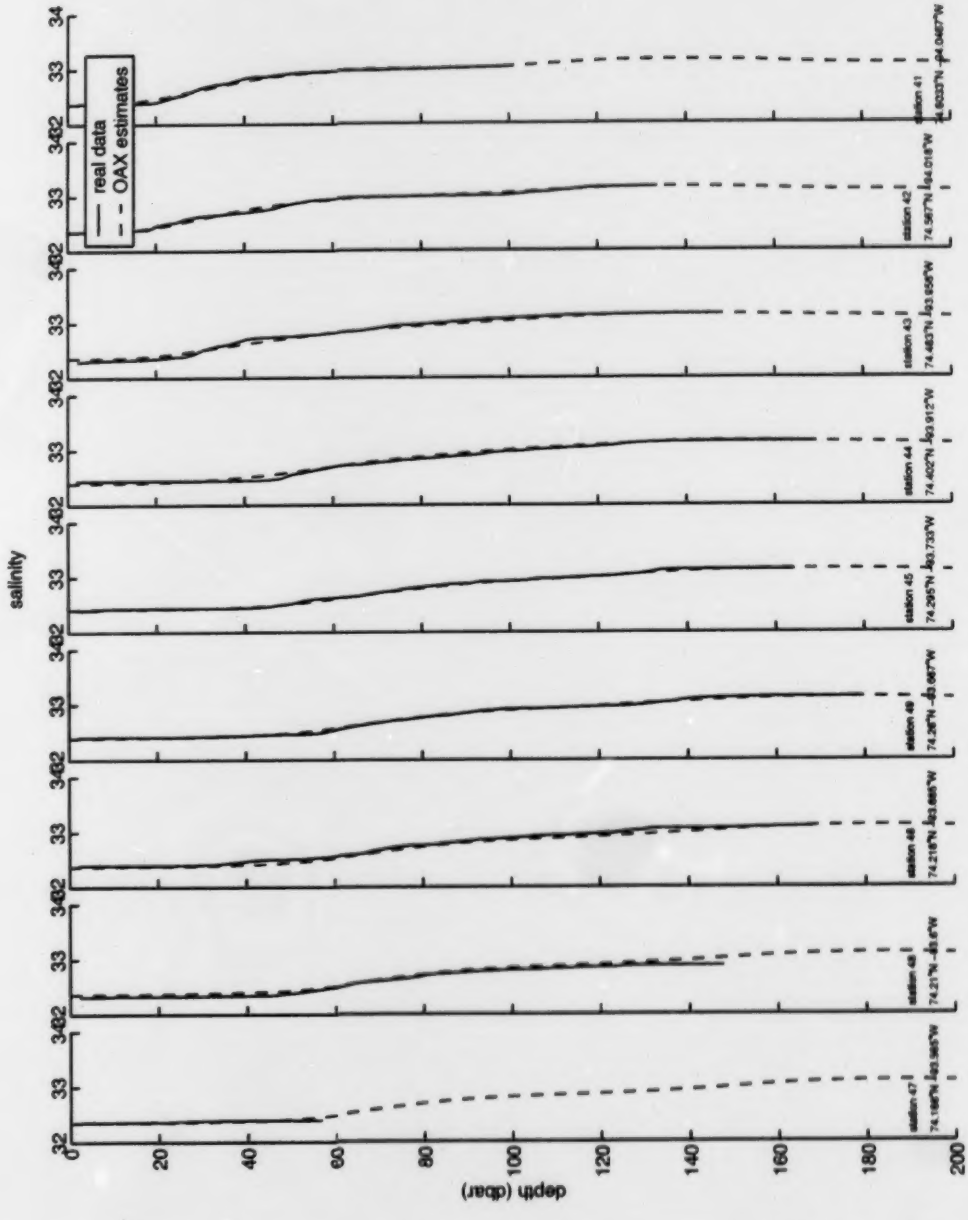

Figure 4 Profiles of April 22, 1982 CTD salinity measurements with OAX estimates for western Barrow Strait transect.

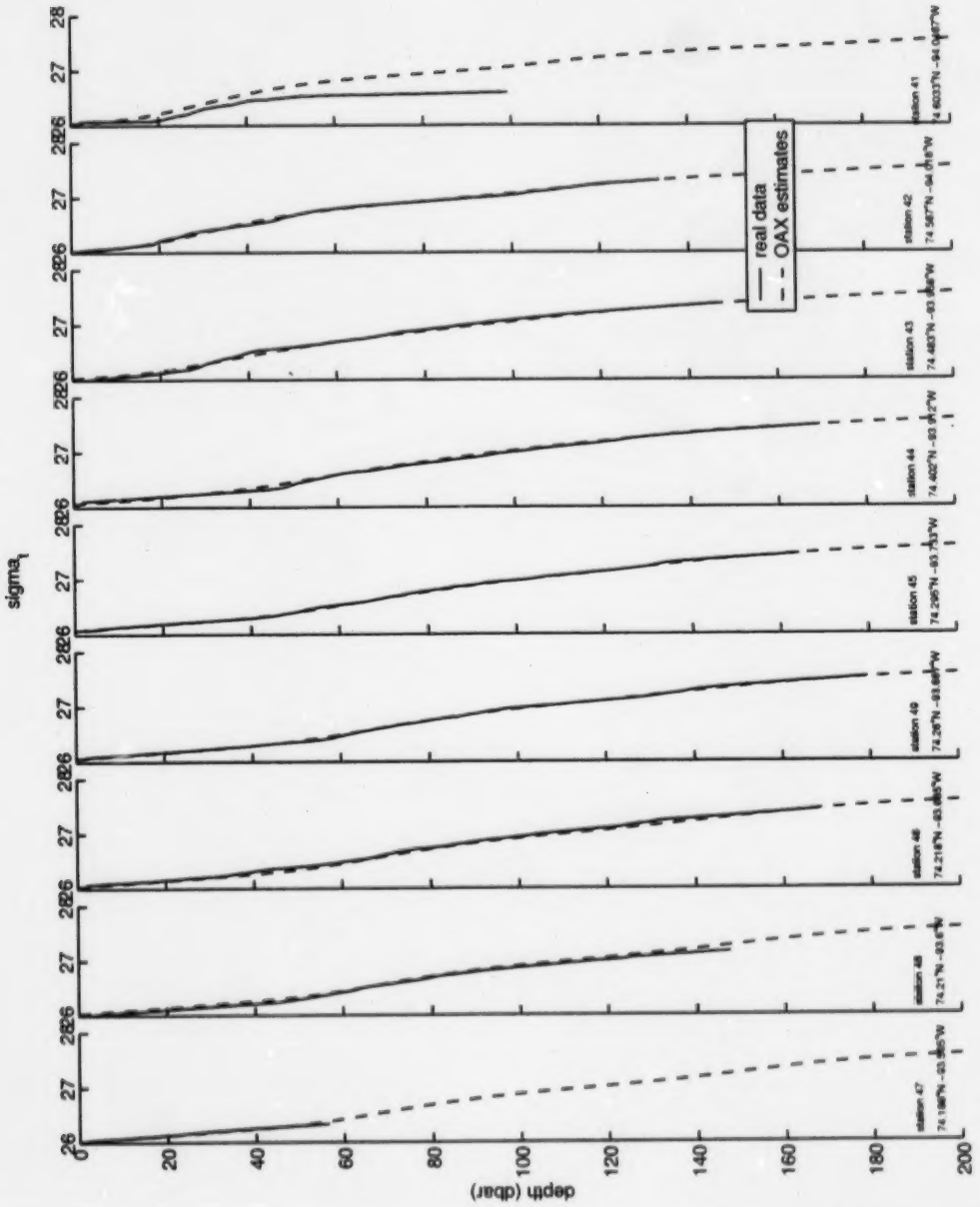

Figure 5 The density field for the April 22, 1982 western Barrow Strait transect data computed from OAX estimates of temperature and salinity and computed from actual temperature and salinity measurements.

The density (σ_t) field was computed from the OAX estimates and from the measurements and compared in Figure 5.

Geostrophic velocities were computed for mid-grid (mid-station) points as the sum of the baroclinic and barotropic currents. The barotropic part was taken as that part of the total velocity that is associated with the slope of the sea surface and the baroclinic part was that which is associated only with the slope of the isopycnal surfaces. The computation of the baroclinic velocity comes from the algorithm defined for each reference depth, *j*: $V_{bc}(j\text{-}1) + V_{bc}(j)$ where $V_{bc}(j) = -(g/\rho_o f)\, \partial\sigma_t/\partial s\, dz$ ($f = 1.4x10^{-4}\ s^{-1}$; $dz = 5\ m$) and $V_{bc}(z=0) = -(g/\rho_o f)\, \partial\sigma_t/\partial s\, dz$. Corresponding barotropic and baroclinic transports for each mid-station position are respectively defined as: 1. the product of the barotropic velocity and bottom depth and 2. the sum of the product of the baroclinic velocities and the depth interval ($\int V_{bc}\, dz$). The total transport for each mid-station position is computed as their sum. The volume transport (flux) for the entire cross-section is the sum of the product of the transports and the distances between mid-station points ($\int$ *transport ds*).

4 RESULTS

Herein lie the estimates for total volume transport (flux) through the Barrow Strait cross-sections. Positive flux values are eastward for the eastern and western cross-sections and southward for the northern cross-section. Positive relative velocities ("out of the page") that are displayed in contoured cross-sections are eastward flow for eastern and western cross-sections and southward flow for the northern cross-section.

Table 3 Table of volume transports. Values are in Sverdrups (1 Sv = 1 x 10^6 m^3s^{-1}).

			Barotropic (Sv)	Baroclinic (Sv)	Total (Sv)
summer	EAST	1998	12.1	-4.6	7.5
		1999	2.7	-1.8	1.0
		2000	0.1	4.7	4.8
	WEST	1980	5.6	-4.6	1.0
		1998	4.9	-4.3	0.6
		1999	-0.7	1.6	0.8
		2000	12.9	-10.3	2.4
	NORTH	1998	-0.1	0.8	0.6
		1999	0.9	-0.1	0.8
		2000	-2.0	2.6	0.6
winter	EAST	1981	4.2	-2.9	1.3
		day 90 1982	3.4	-2.1	1.3
		1983	5.7	-3.9	1.7
	WEST	1981	6.4	-3.9	2.4
		day 112 1982	3.4	-1.8	1.7
		day 112 1983	4.6	-2.7	1.9
	NORTH	1981	-2.1	1.8	-0.3
		1982	0.7	-0.4	0.2
		1983	-0.3	0.4	0.1

Contours of the computed relative geostrophic velocities are shown on the next several pages for summer and winter for the three transects (east, west, and north Barrow Strait).

Preliminary results from the 1998-2000 current meter mooring data (east Barrow Strait) show similar transport values and large variability. From Table 3 it can be seen that summer values have the greatest magnitude of the year and have the largest variability while winter values are half as large with less variability.

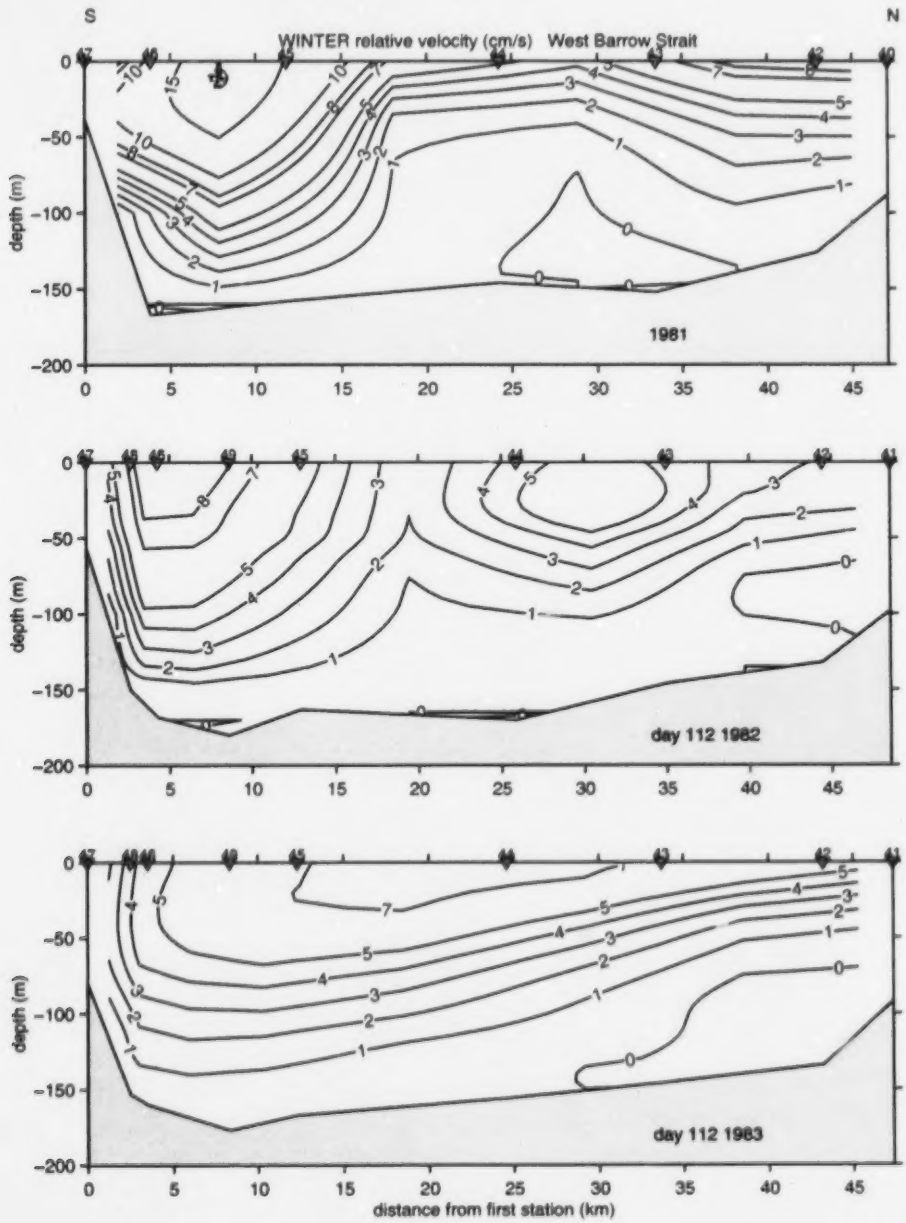

Figure 6 Relative velocities for west Barrow Strait in winter reveal an eastward current towards the center of the strait that combined into one in 1983.

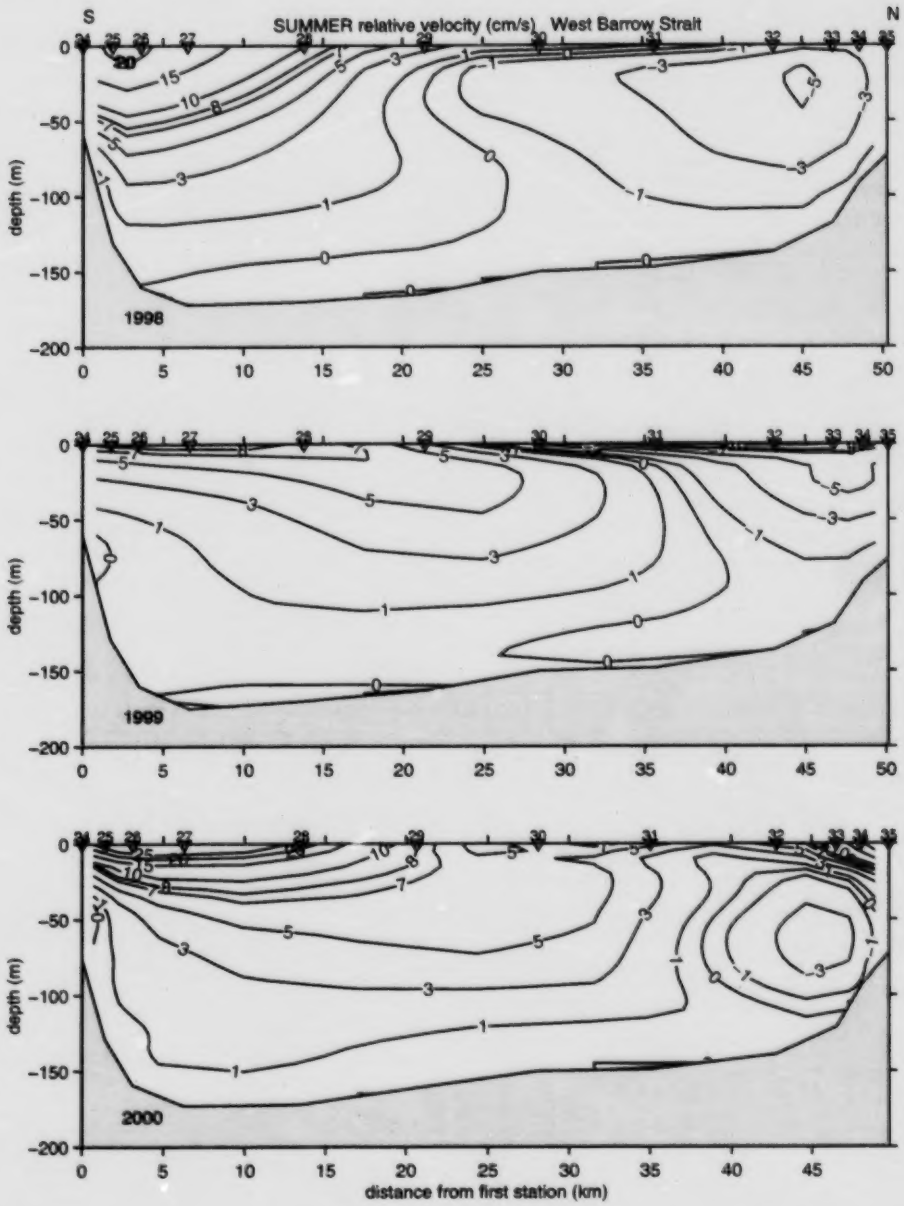

Figure 7 Relative velocities for west Barrow Strait in summer reveal strong gradients at the northern end at the surface in 1999 and coastal effects in 2000.

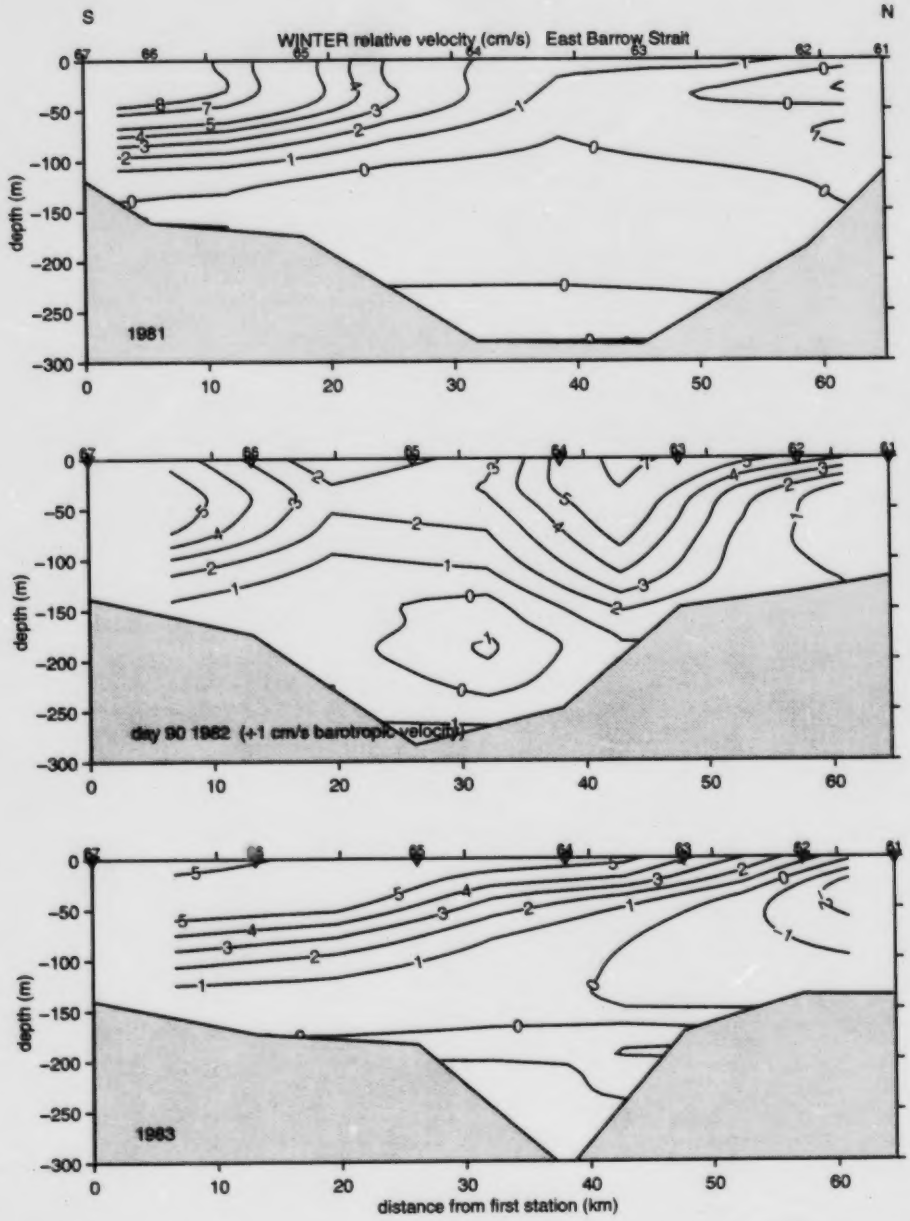

Figure 8 Relative velocities for east Barrow Strait in winter. The cross-section of the 1982 relative velocities includes a 1 cm/s mean current that was added to all values. Bottom contours differ from year to year because different soundings for the stations were recorded from year to year.

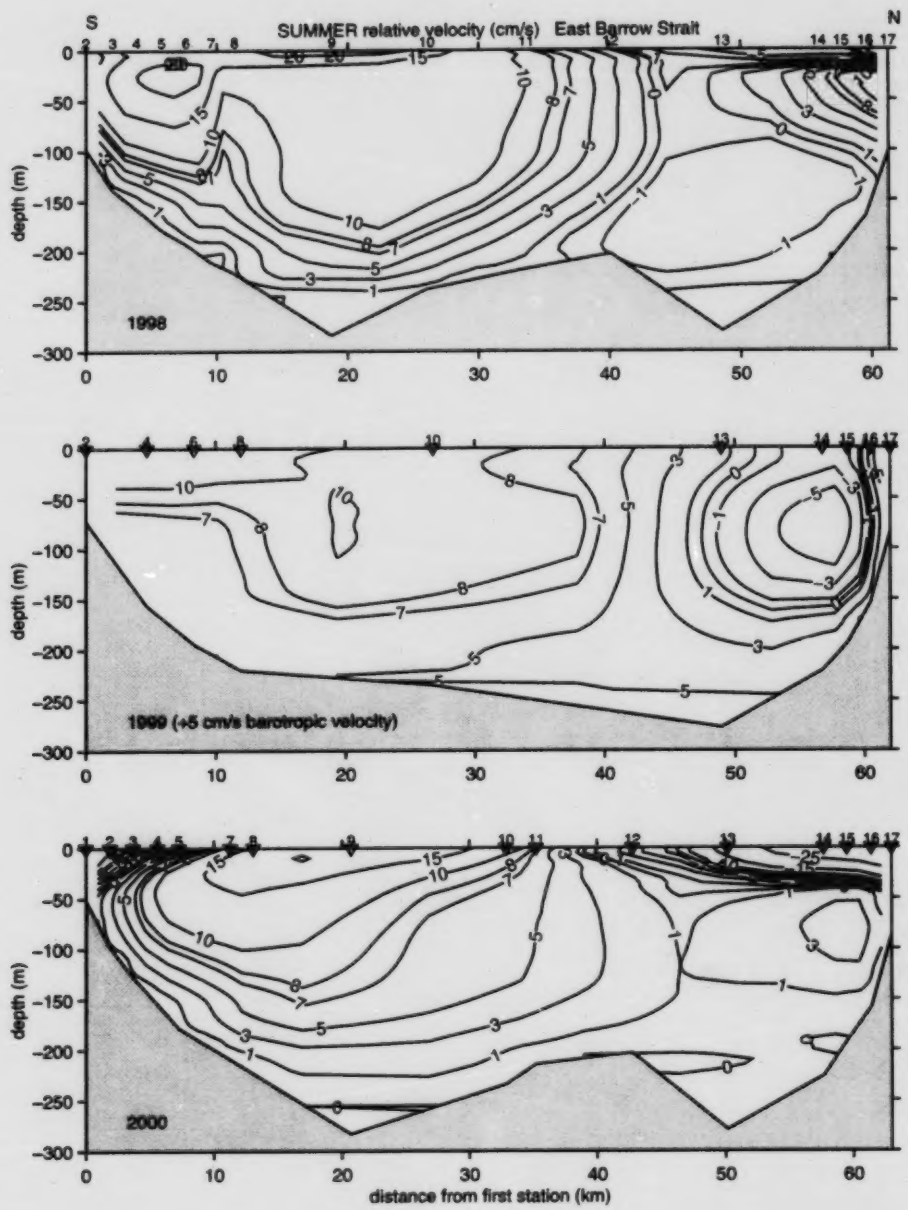

Figure 9 Relative velocities for east Barrow Strait in summer. The cross-section of 1999 relative velocities in east Barrow Strait includes a 5 cm/s mean current that was added to all values. Bottom contours are different in 1999 because different soundings for the stations were recorded in that year.

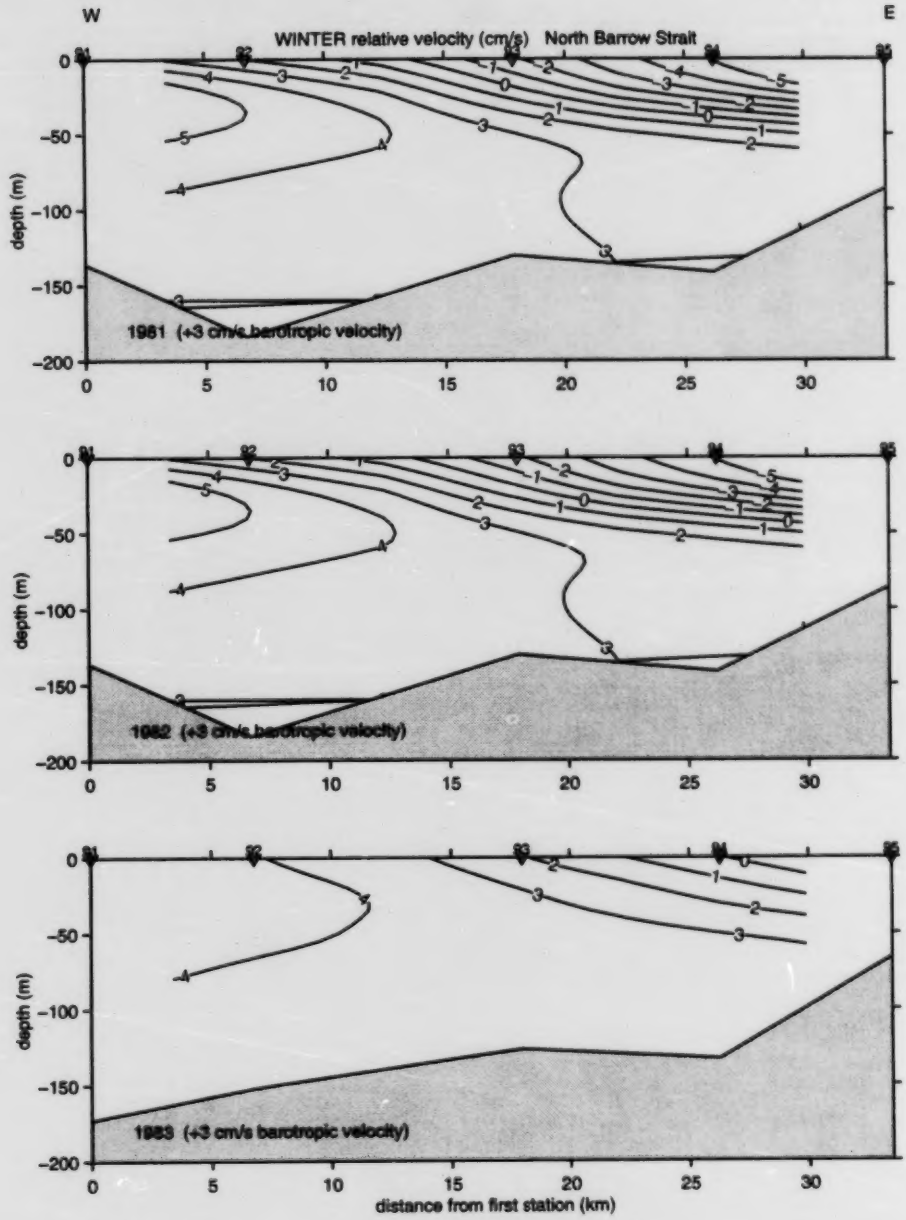

Figure 10 Relative velocities for north Barrow Strait in winter.

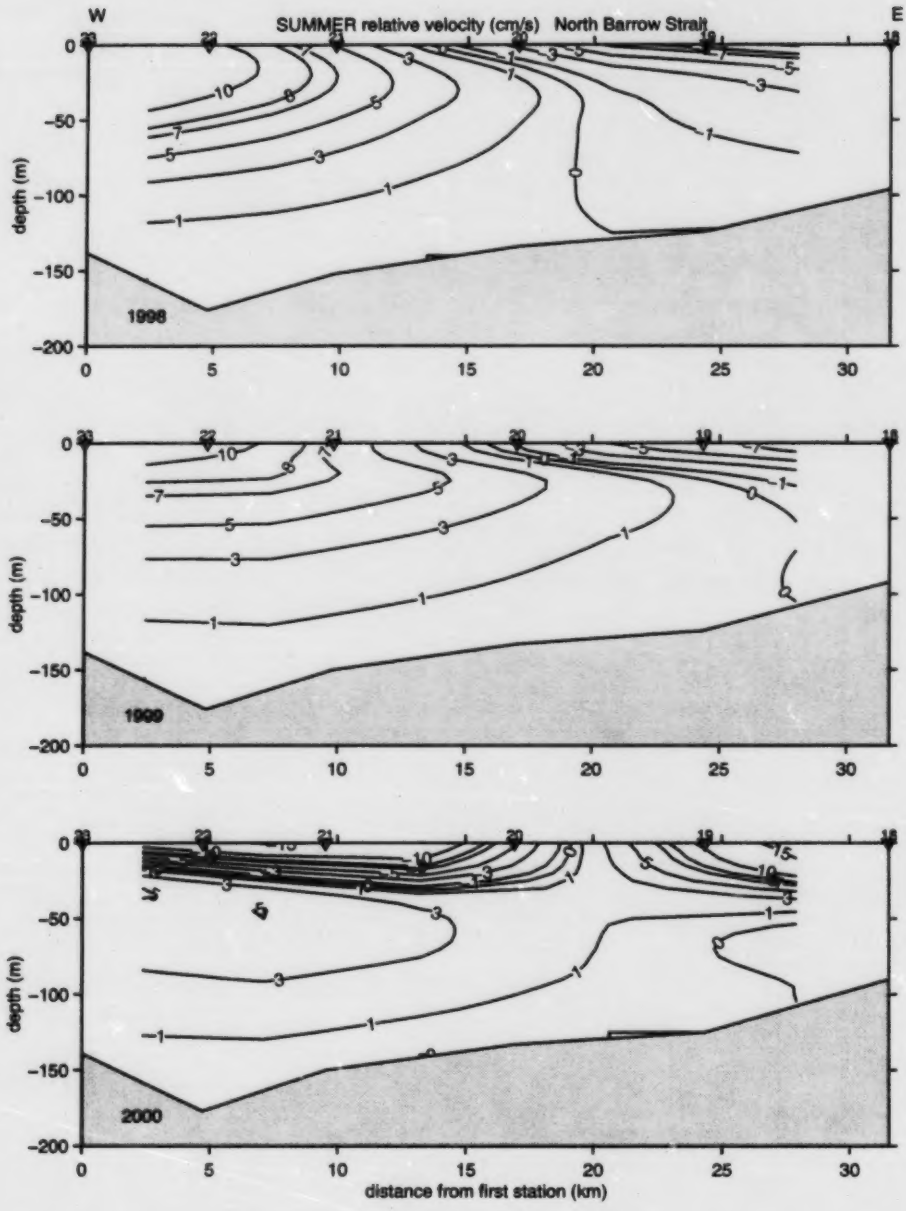

Figure 11 Relative velocities for north Barrow Strait in summer.

ACKNOWLEDGEMENT

The researchers involved in this project gratefully acknowledge the support from the Panel of Energy Research and Development. We also thank C. Hannah and S. Oakey for technical advice and provision of computer code. J. Hamilton is thanked for providing the 1998-2000 CTD data.

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Prinsenberg, S. J. and E. B. Bennett, 1987. Mixing and transports in Barrow Strait, the central part of the Northwest passage, *Continental Shelf Research*, vol. 7, no. 8: 913-935.

6 APPENDIX

6.1 Winter

6.1.1 1981

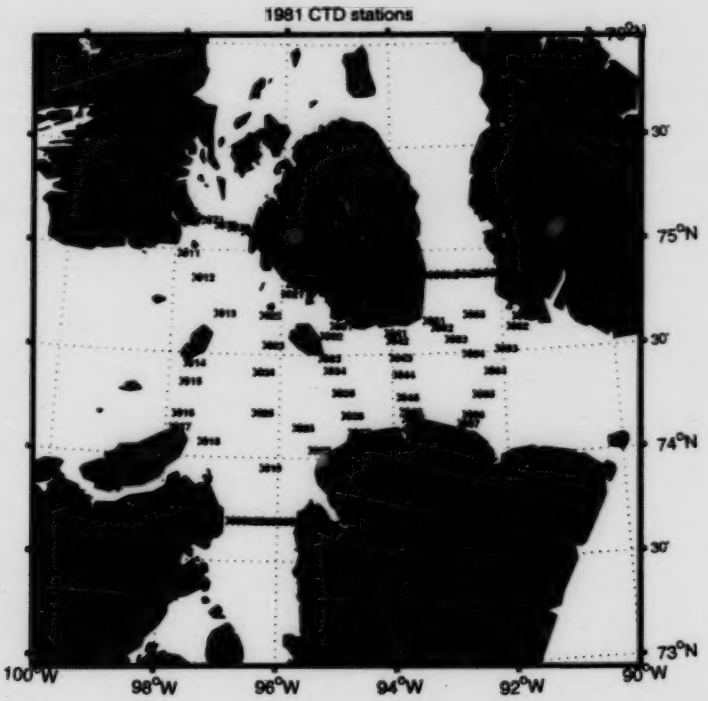

Figure 12 Map of CTD station locations for 1981 survey of Barrow Strait region.

6.1.1.1 West Barrow

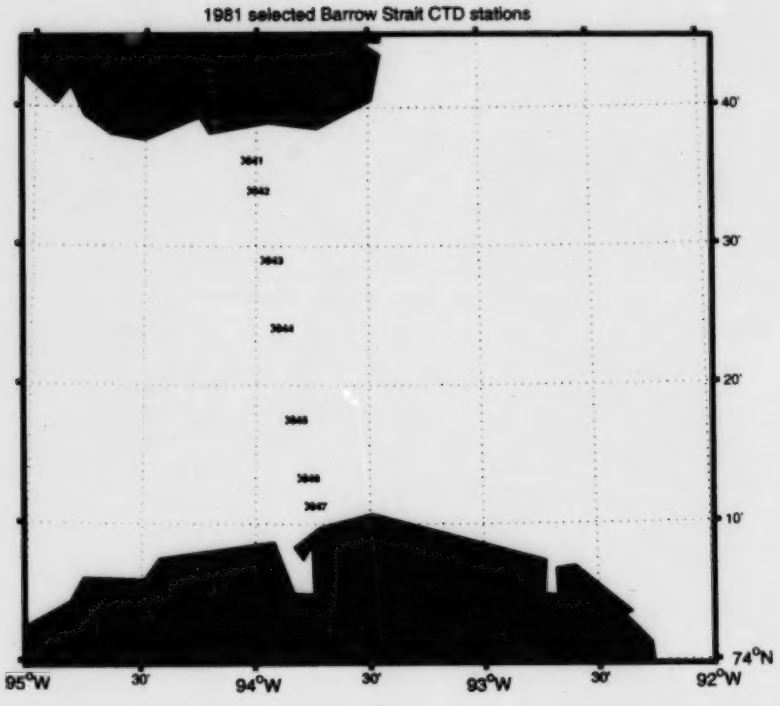

Figure 13 CTD stations used in geostrophic transport computations for west Barrow Strait in 1981.

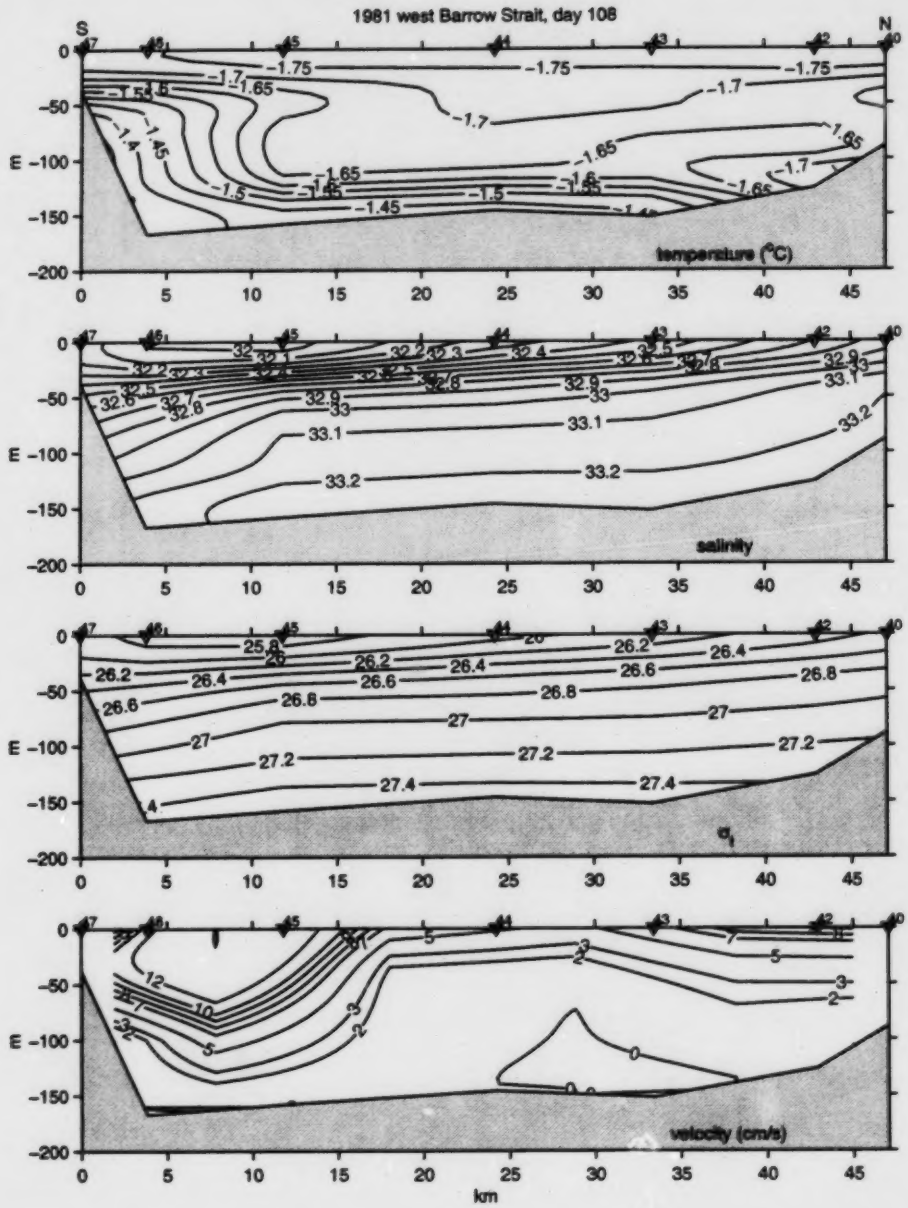

Figure 14 Cross-section of temperature, salinity, density, and relative velocity for 18 April 1981.

6.1.1.2 East Barrow

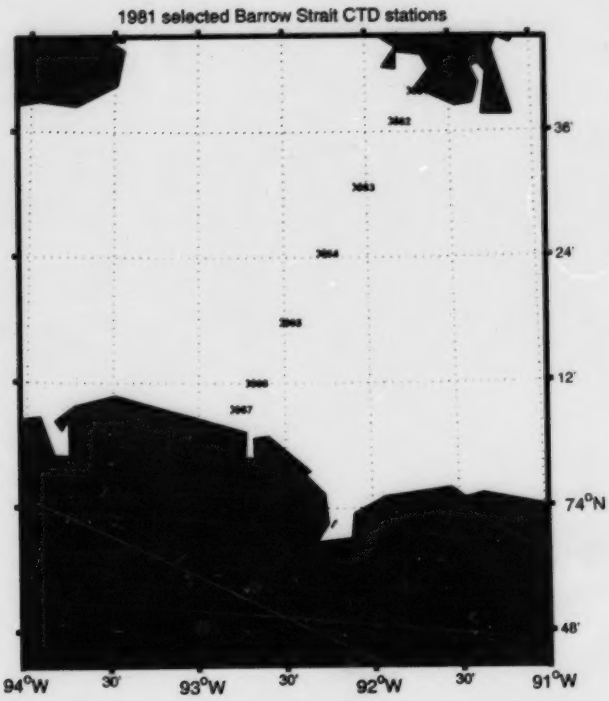

Figure 15 CTD stations used in geostrophic transport computations for east Barrow Strait in 1981.

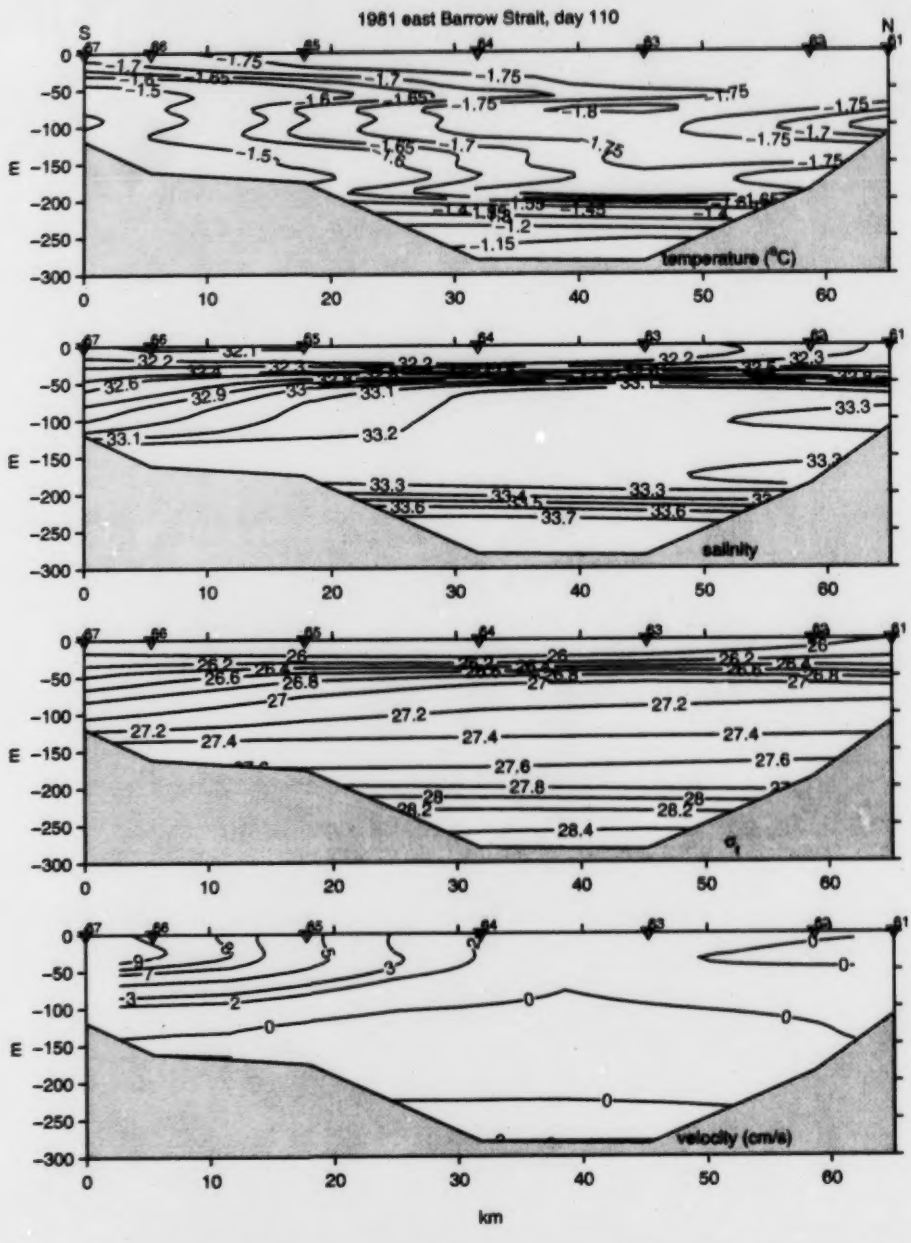

Figure 16 Cross-section of temperature, salinity, density, and relative velocity for 20 April 1981.

6.1.1.3 North Barrow

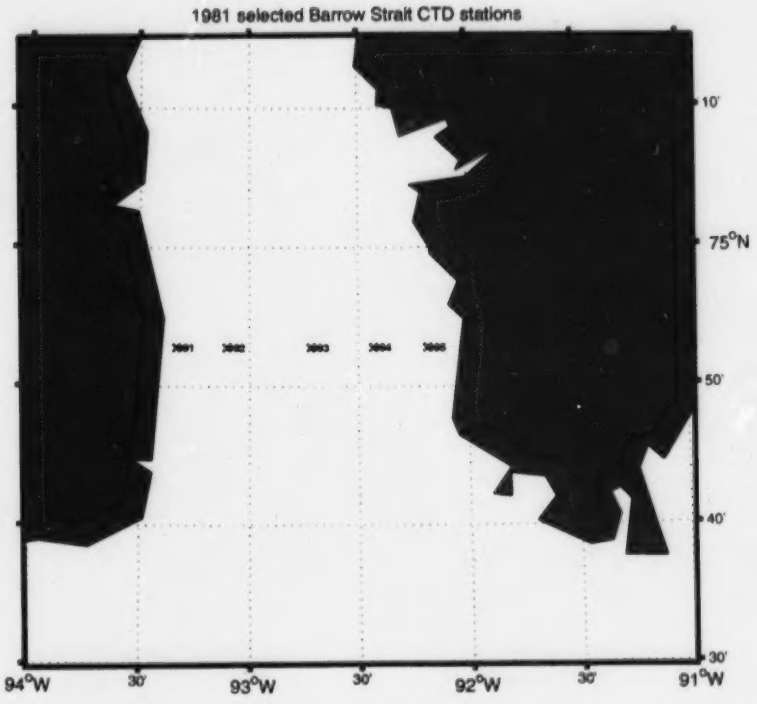

Figure 17 CTD stations used in geostrophic transport computations for north Barrow Strait in 1981.

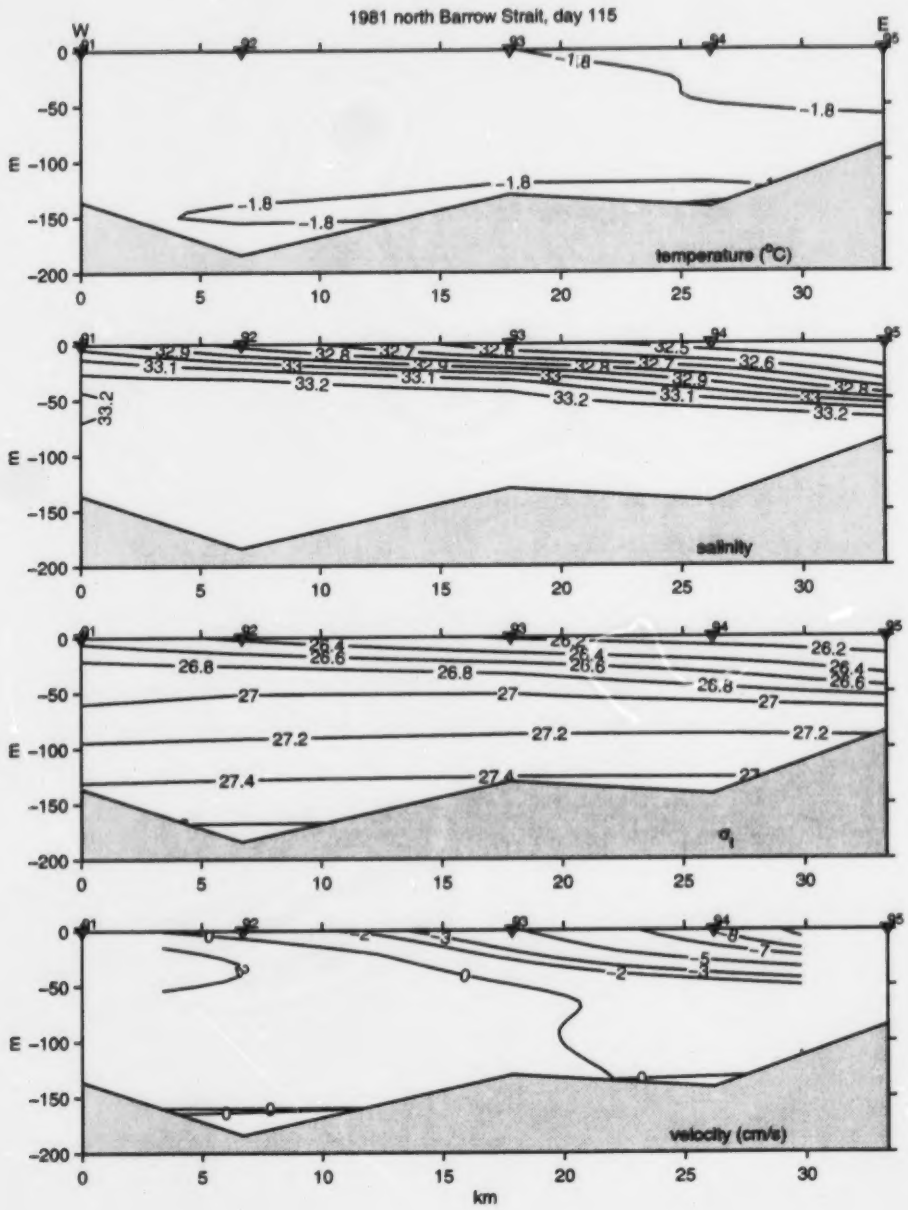

Figure 18 Cross-section of temperature, salinity, density, and relative velocity for 25 April 1981.

6.1.2 1982

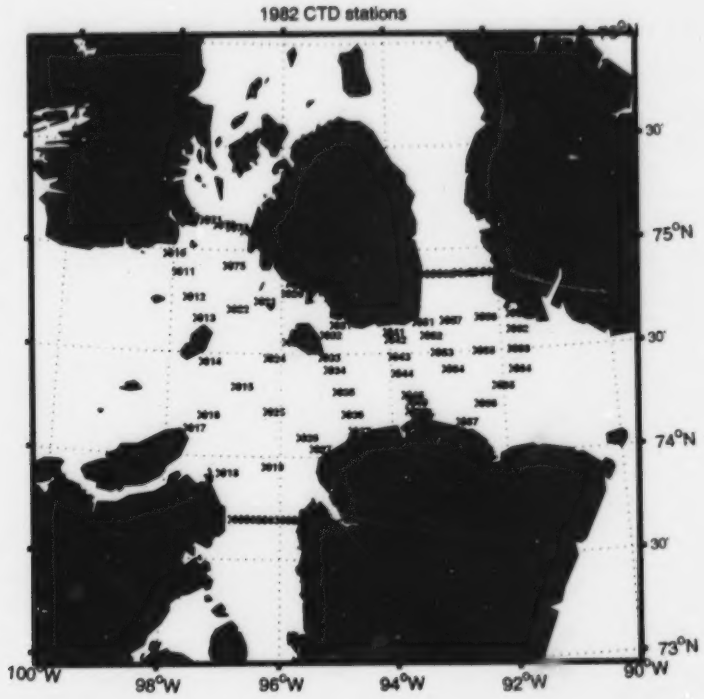

Figure 19 Map of CTD station locations for 1982 survey of Barrow Strait region.

6.1.2.1 West Barrow

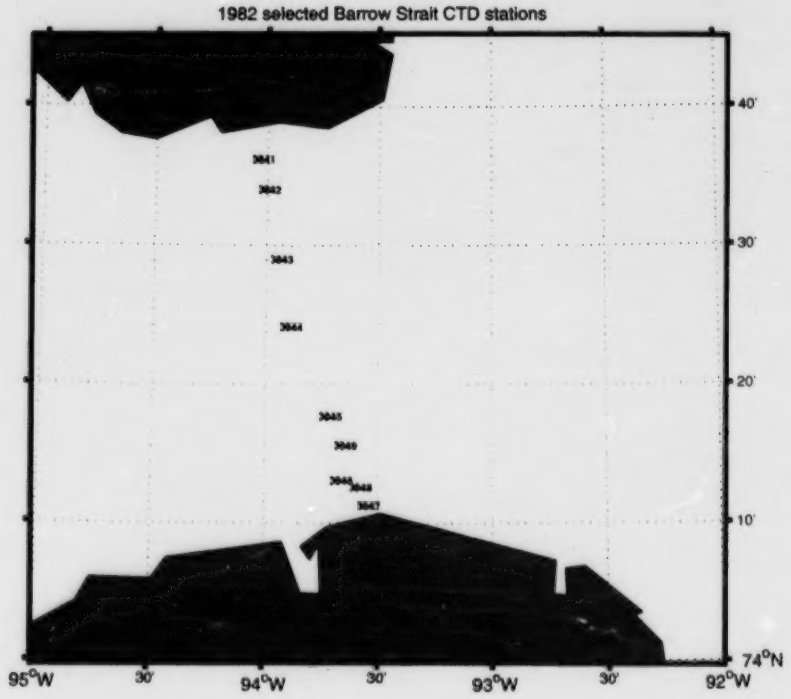

Figure 20 CTD stations used in geostrophic transport computations for west Barrow Strait in 1982.

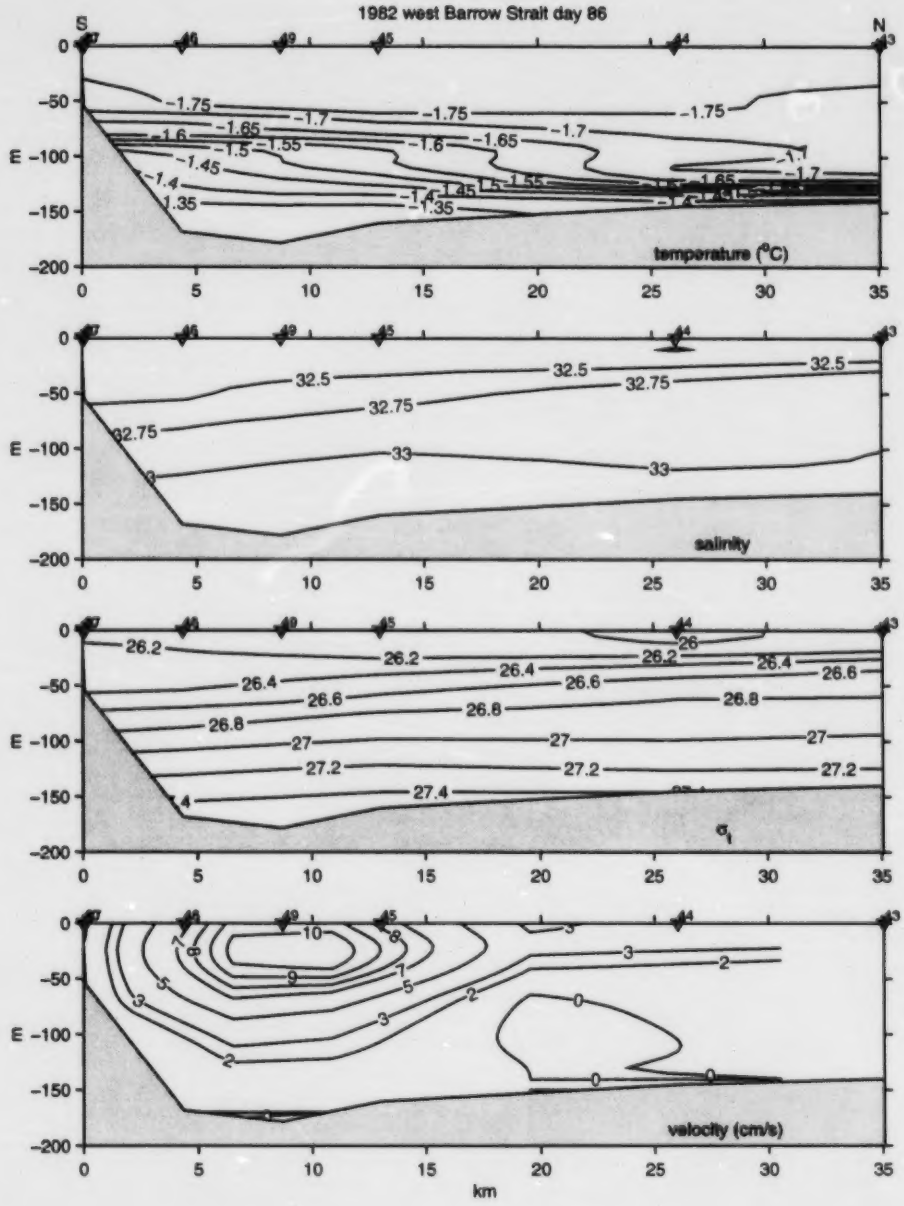

Figure 21 Cross-section of temperature, salinity, density, and relative velocity for 27 March 1982.

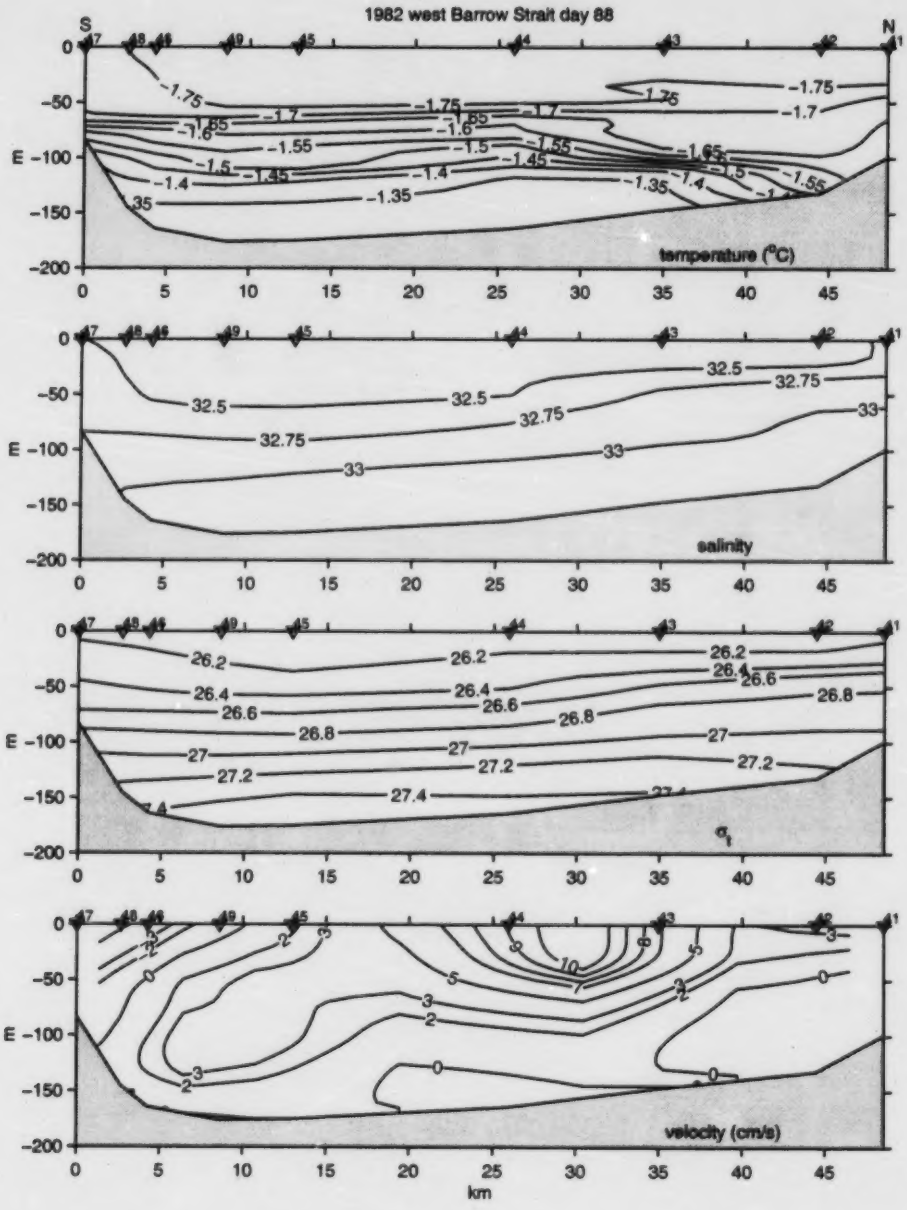

Figure 22 Cross-section of temperature, salinity, density, and relative velocity for 29 March 1982.

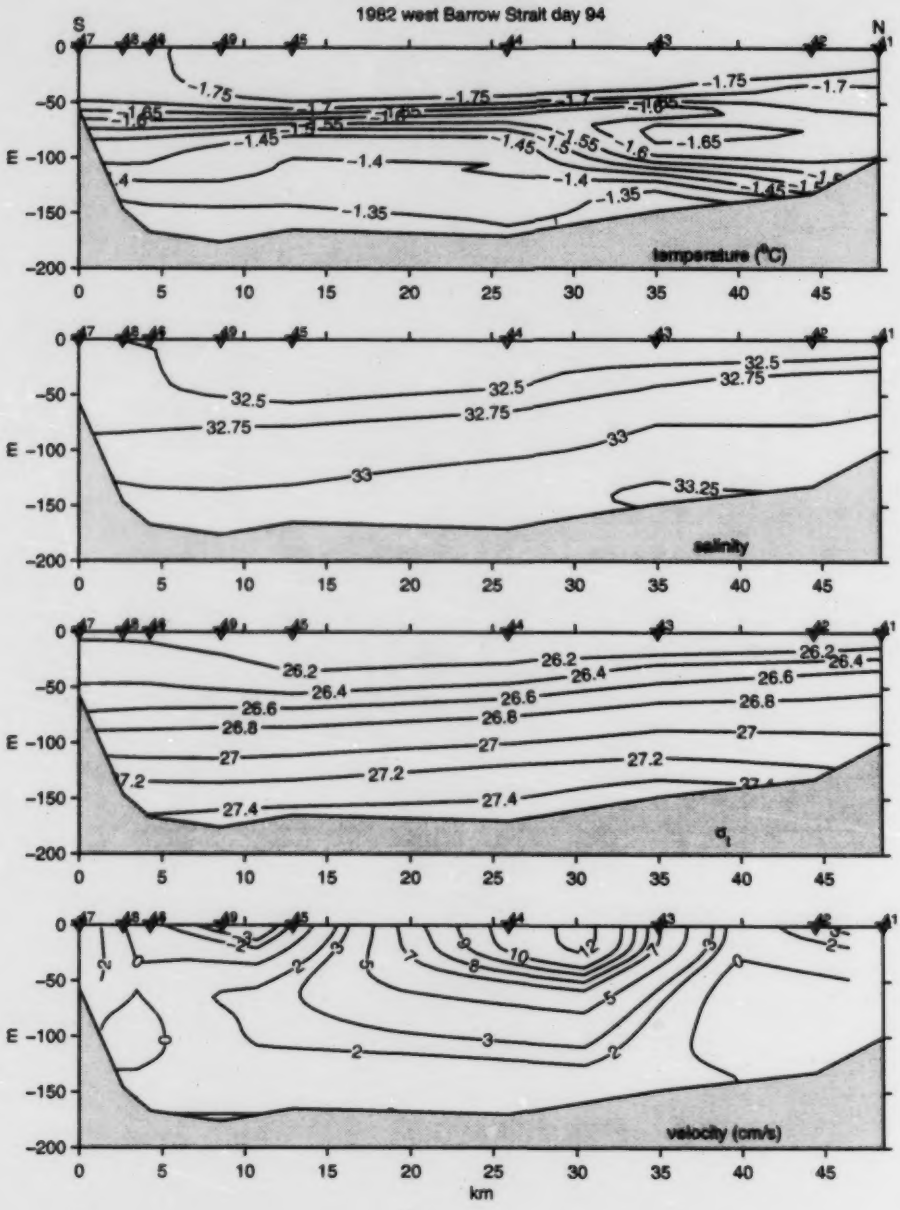

Figure 23 Cross-section of temperature, salinity, density, and relative velocity for 4 April 1982.

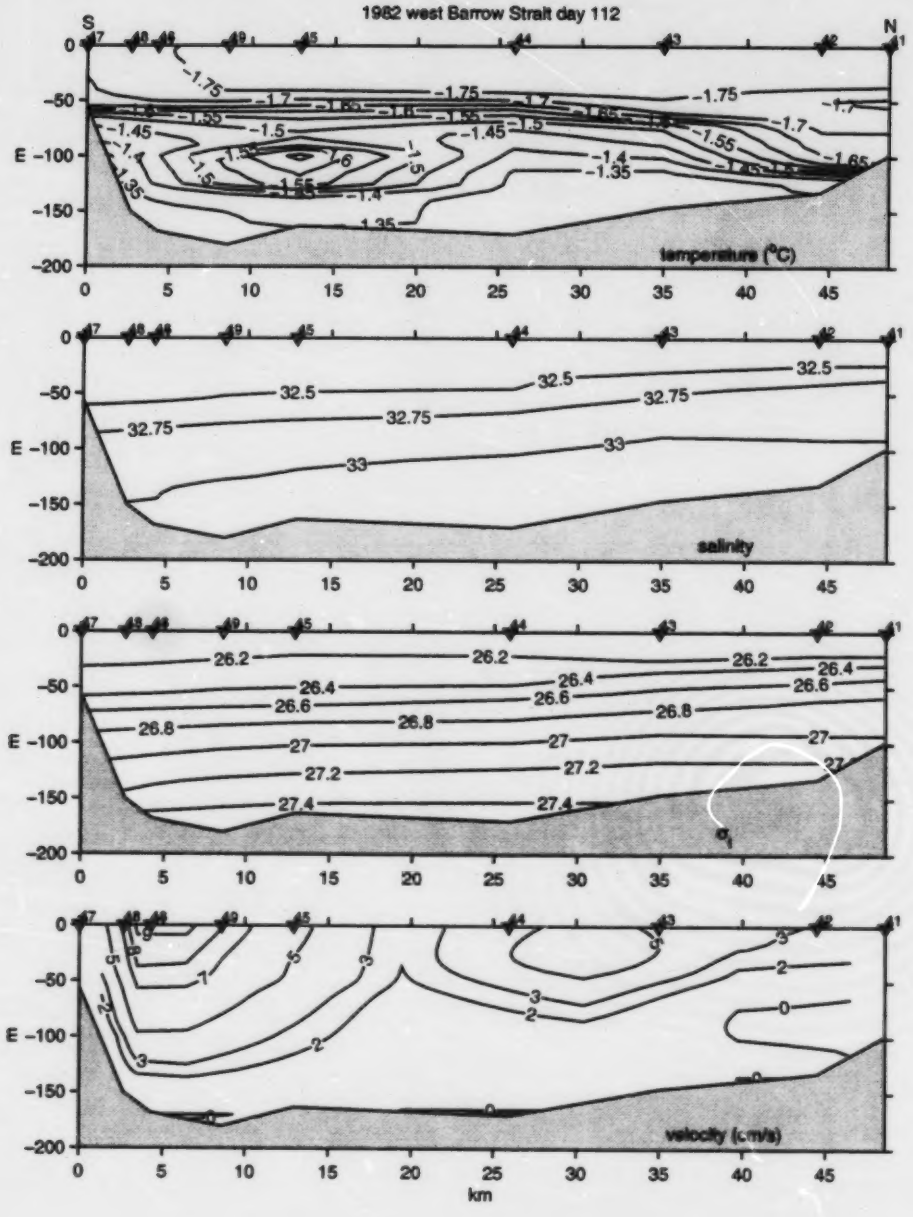

Figure 24 Cross-section of temperature, salinity, density, and relative velocity for 22 April 1982.

6.1.2.2 East Barrow

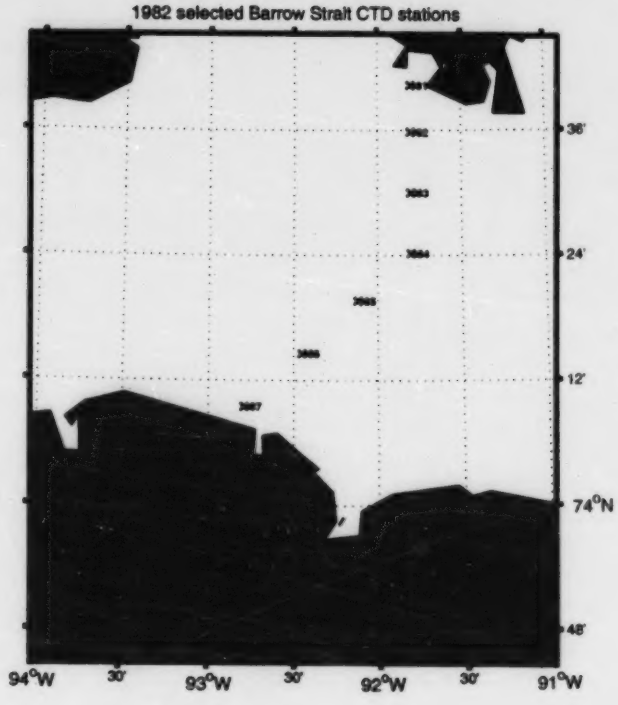

Figure 25 CTD stations used in geostrophic transport computations for east Barrow Strait in 1982.

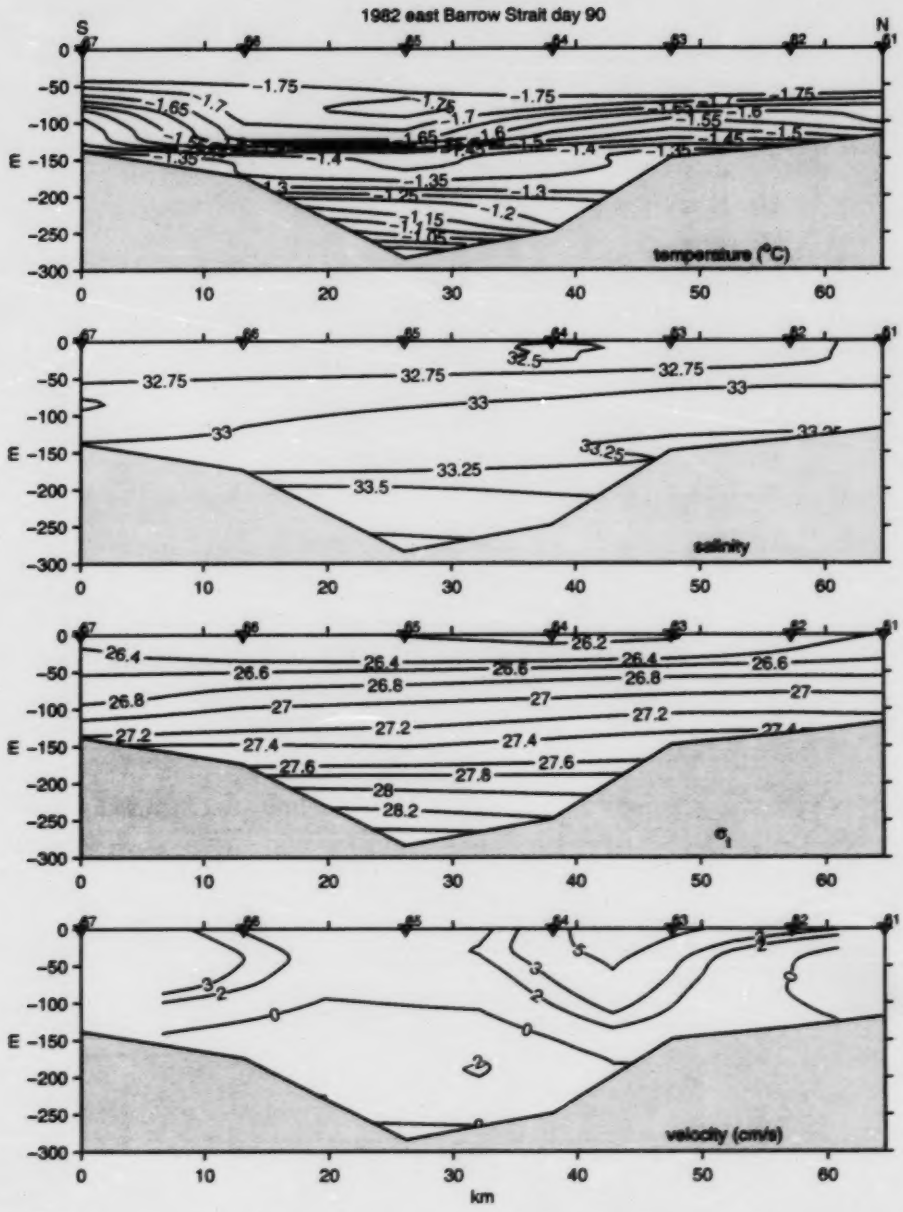

Figure 26 Cross-section of temperature, salinity, density, and relative velocity for 31 March 1982.

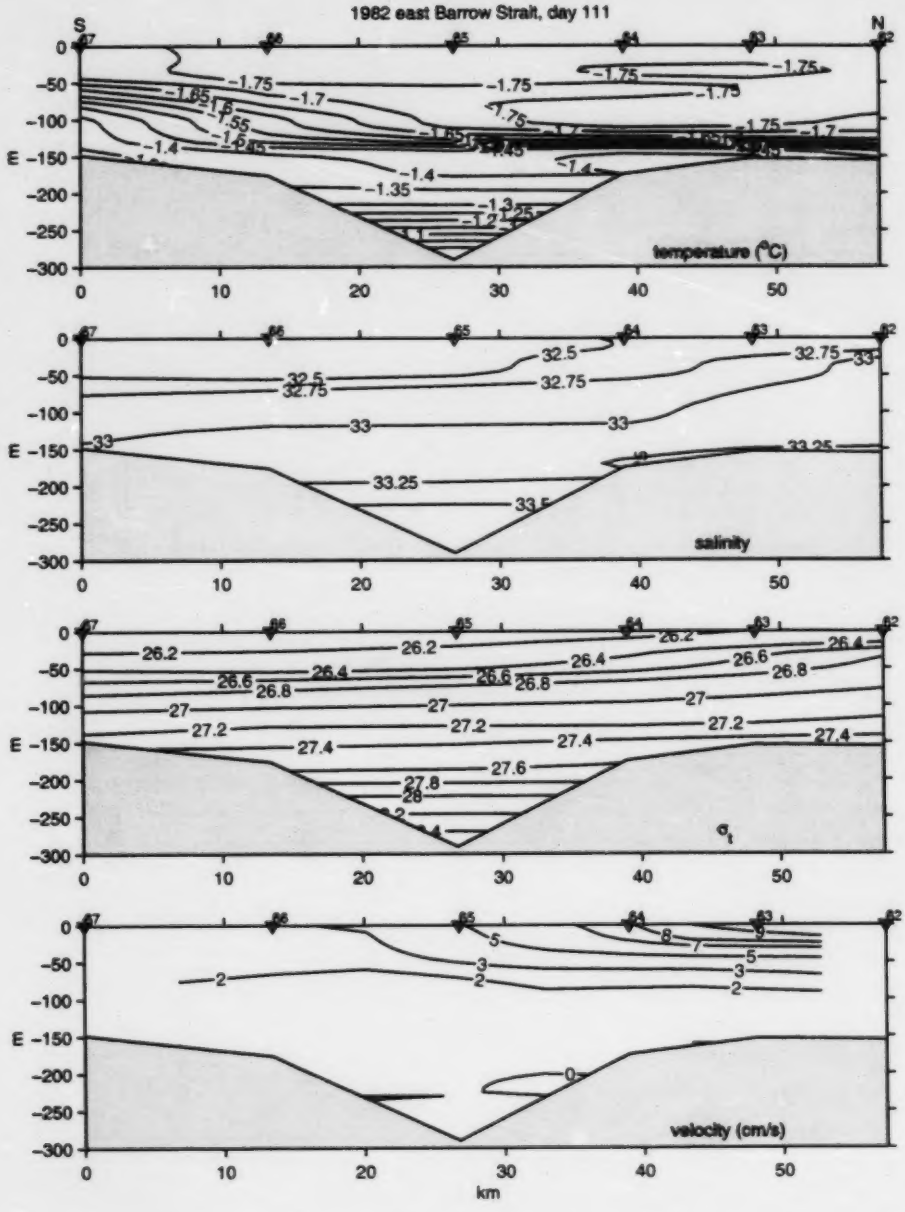

Figure 27 Cross-section of temperature, salinity, density, and relative velocity for 21 April 1982.

6.1.2.3 North Barrow

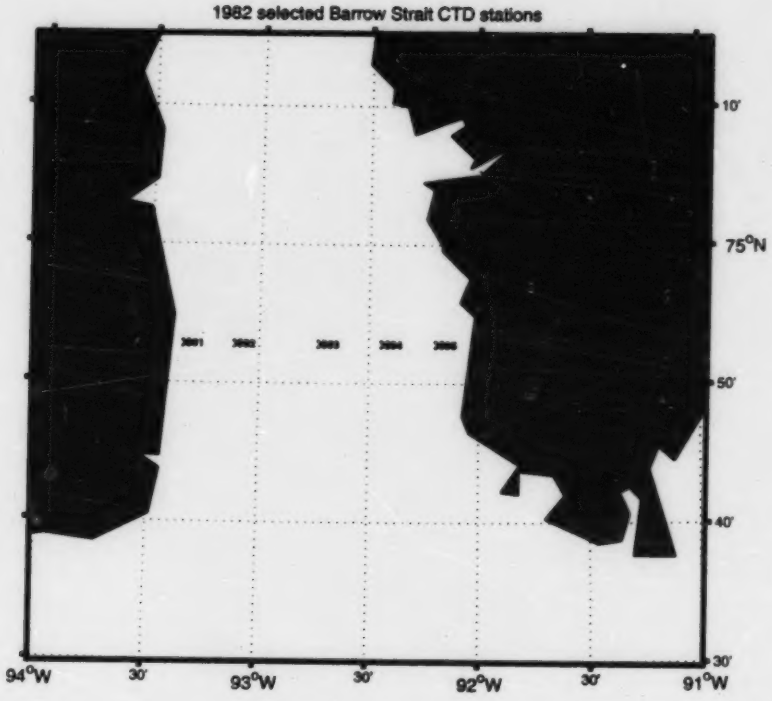

Figure 28 CTD stations used in geostrophic transport computations for north Barrow Strait in 1982.

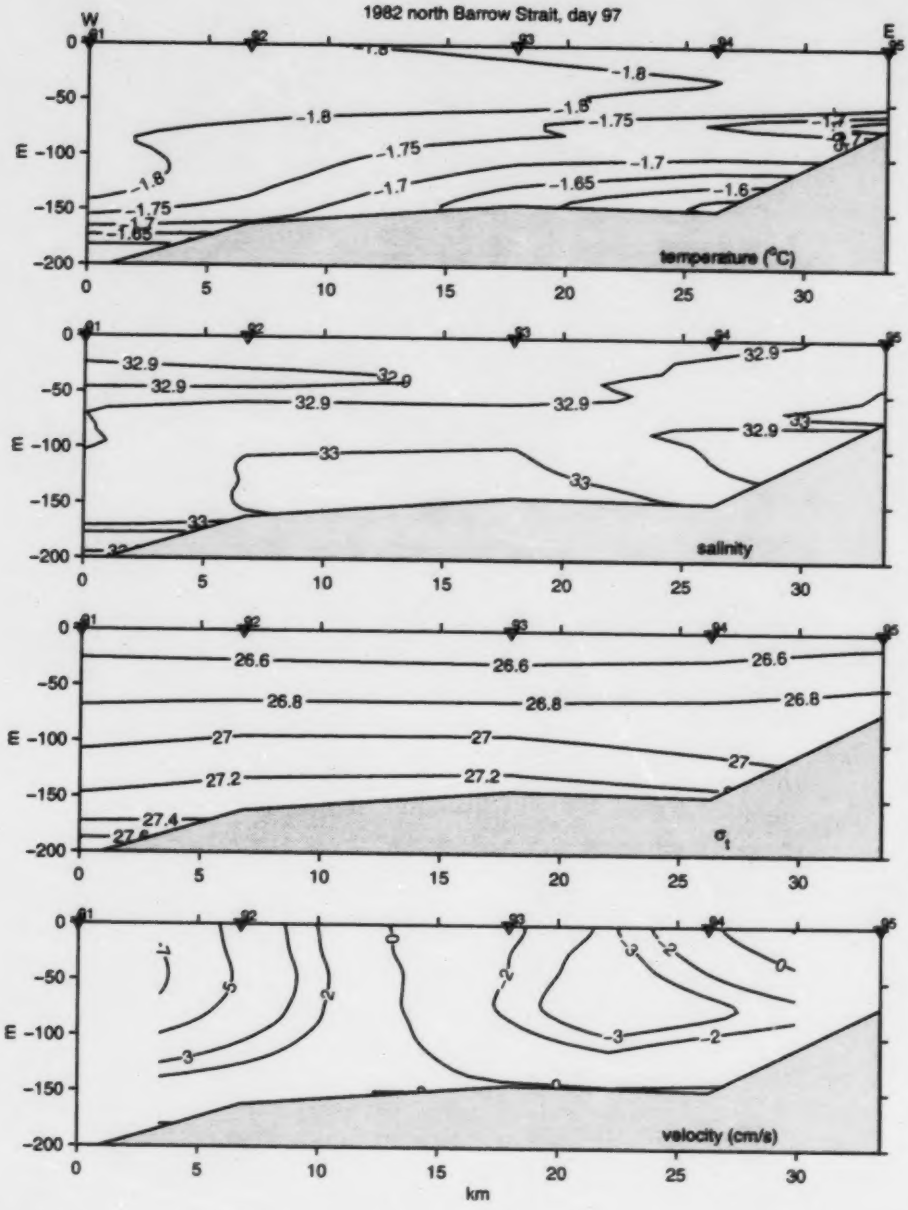

Figure 29 Cross-section of temperature, salinity, density, and relative velocity for 7 April 1982.

6.1.3 1983

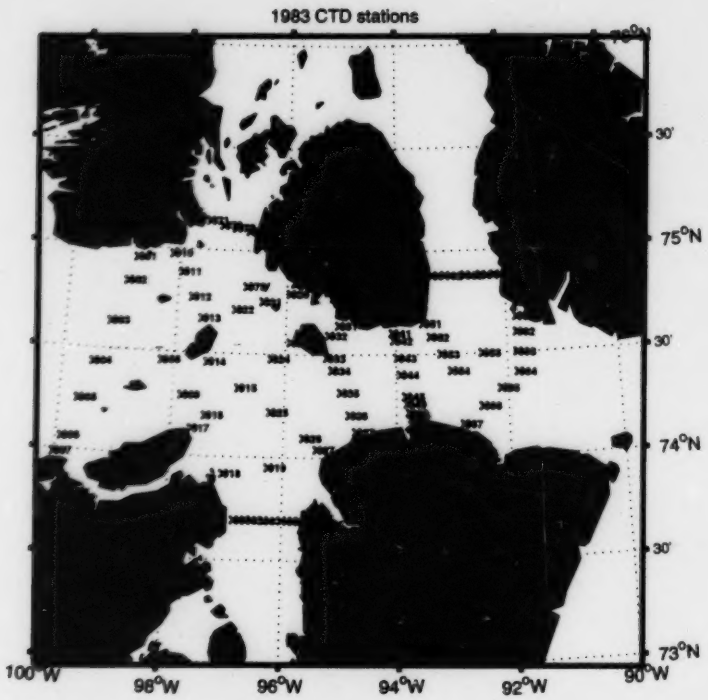

Figure 30 Map of CTD station locations for 1983 survey of Barrow Strait region.

6.1.3.1 West Barrow

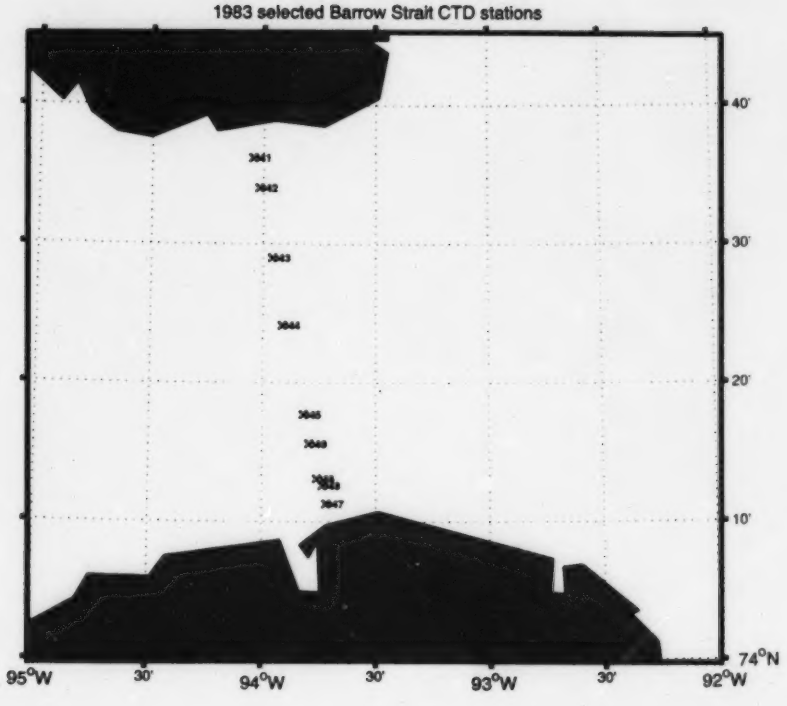

Figure 31 CTD stations used in geostrophic transport computations for west Barrow Strait in 1983.

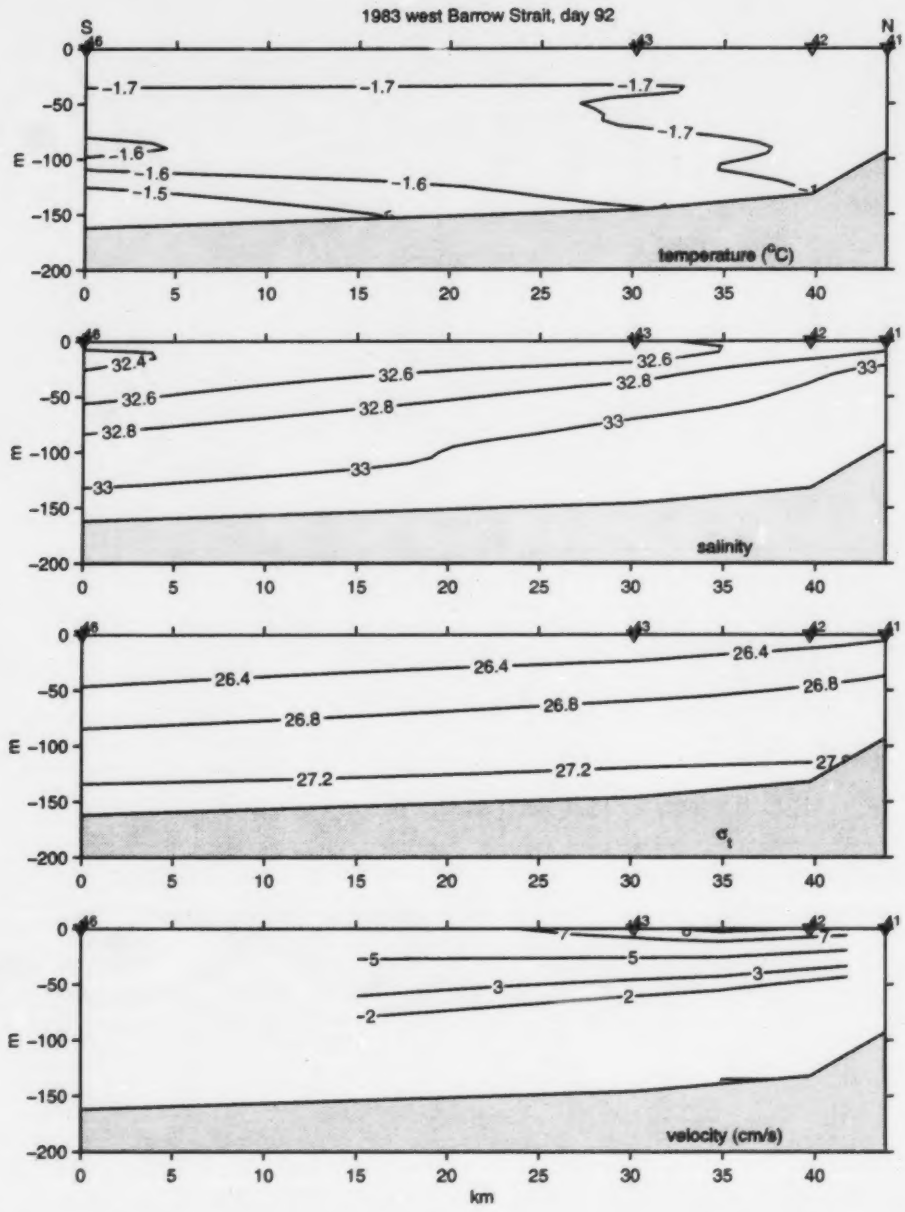

Figure 32 Cross-section of temperature, salinity, density, and relative velocity for 2 April 1983.

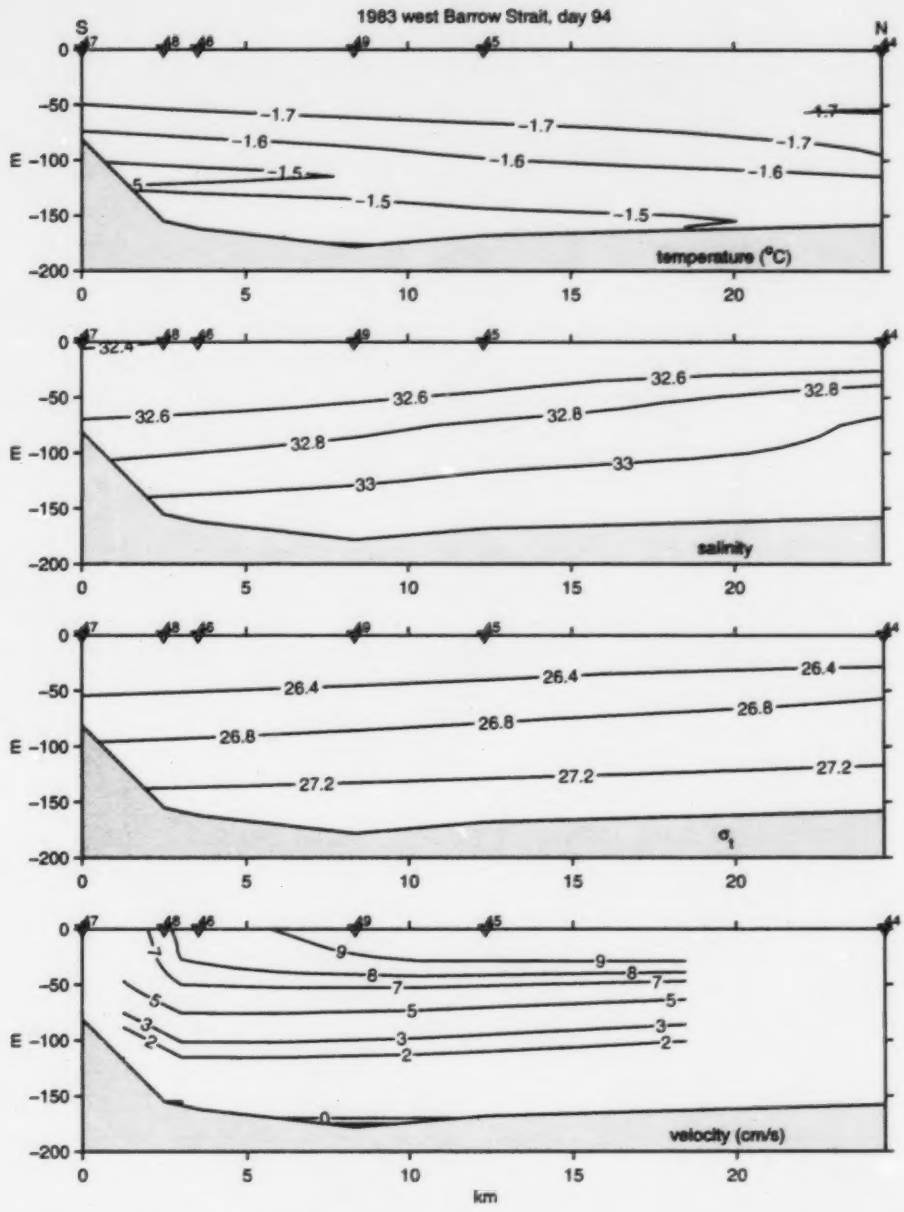

Figure 33 Cross-section of temperature, salinity, density, and relative velocity for 4 April 1983.

6.1.3.2 East Barrow

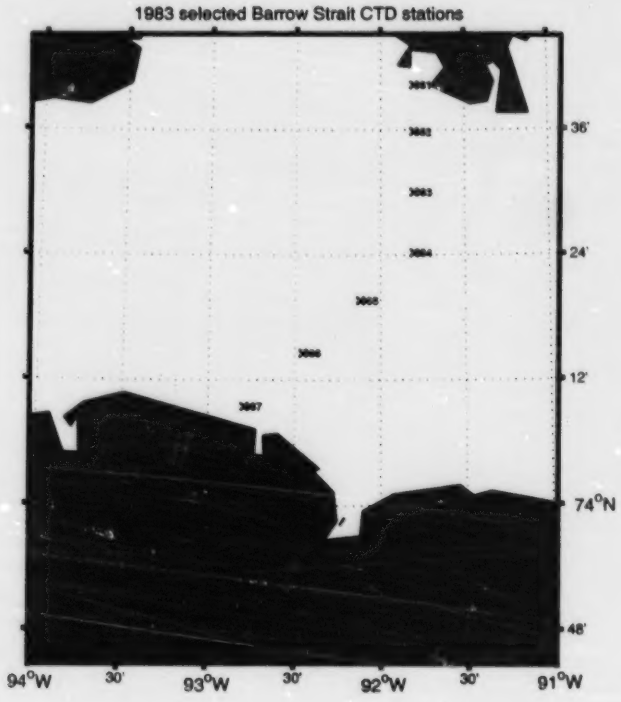

Figure 34 CTD stations used in geostrophic transport computations for east Barrow Strait in 1983.

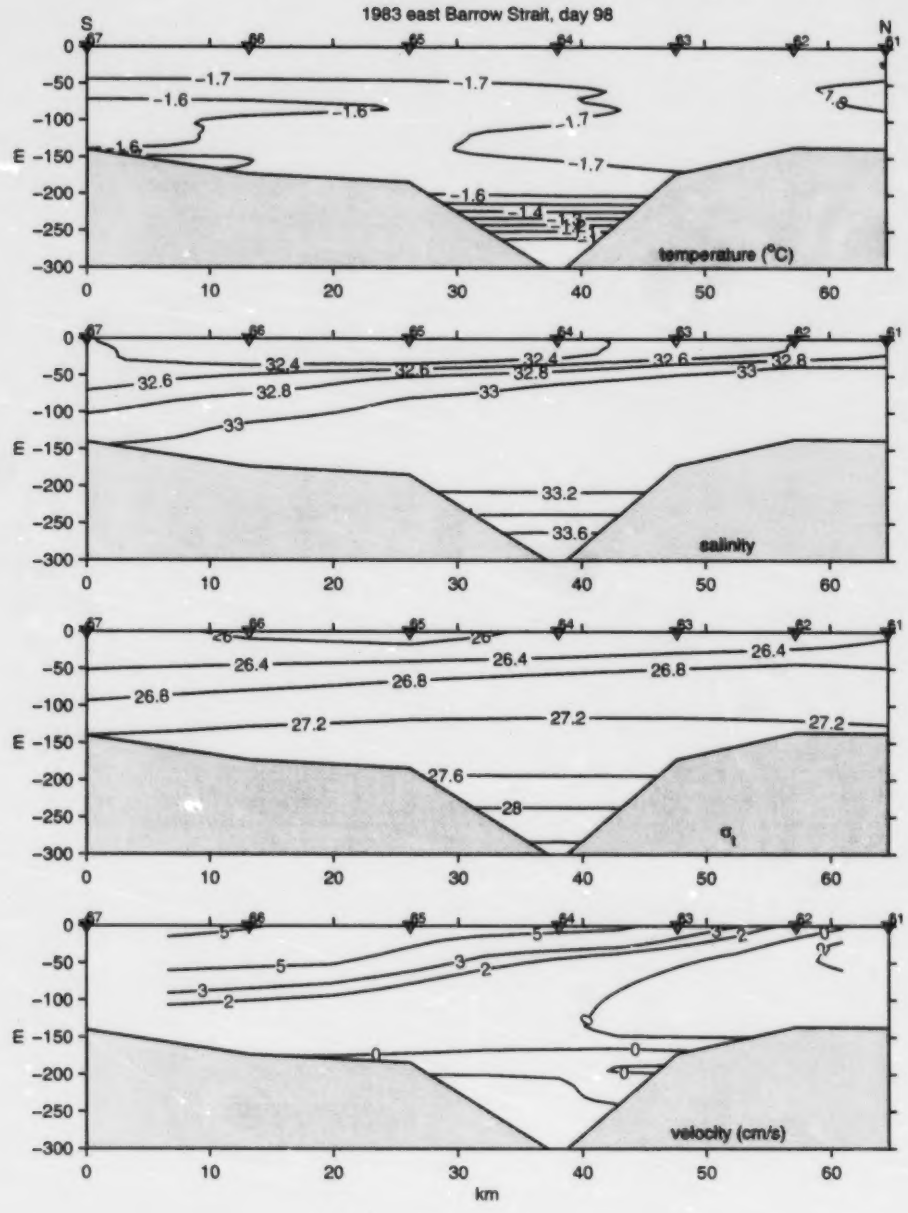

Figure 35 Cross-section of temperature, salinity, density, and relative velocity for 8April 1983.

6.1.3.3 North Barrow

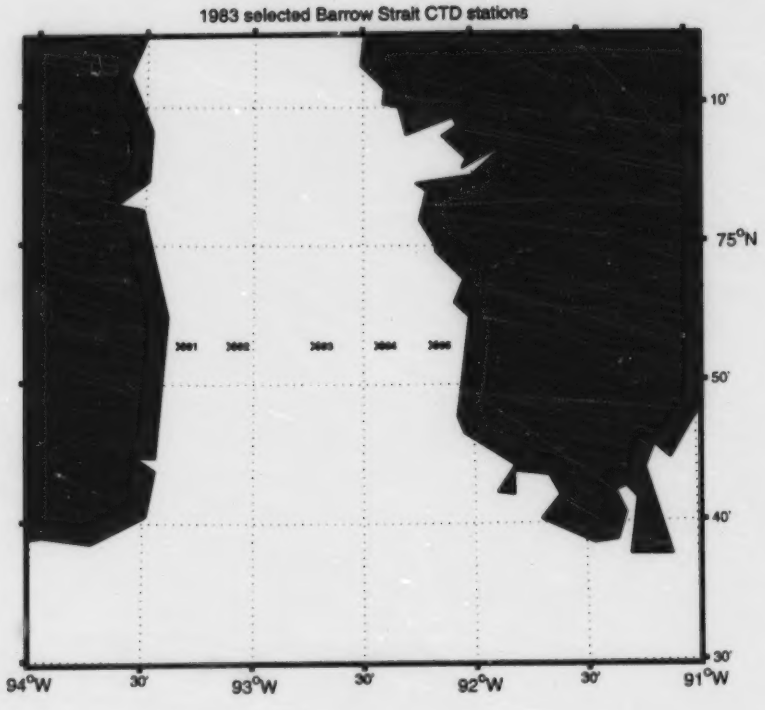

Figure 36 CTD stations used in geostrophic transport computations for east Barrow Strait in 1983.

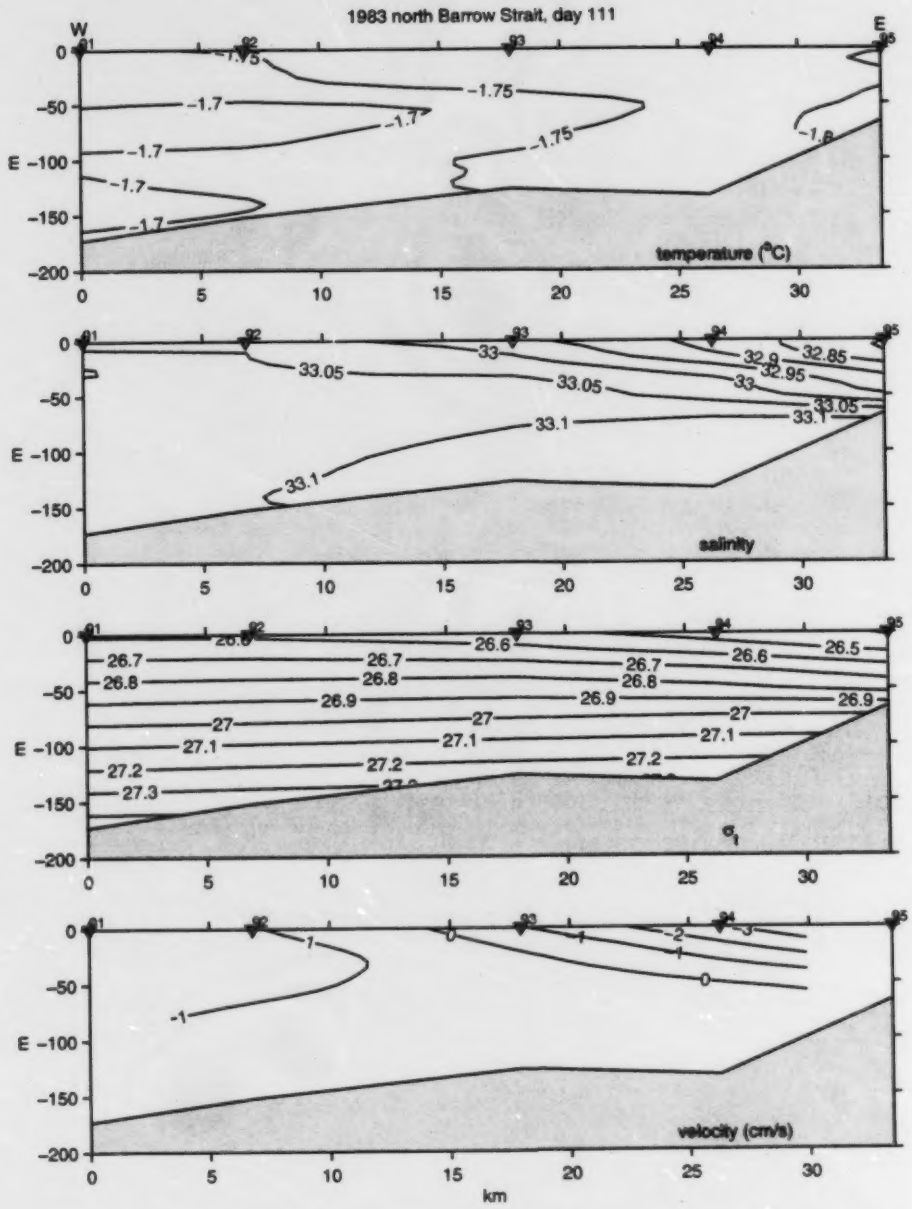

Figure 37 Cross-section of temperature, salinity, density, and relative velocity for 21 April 1983.

6.2 Summer

6.2.1 1998

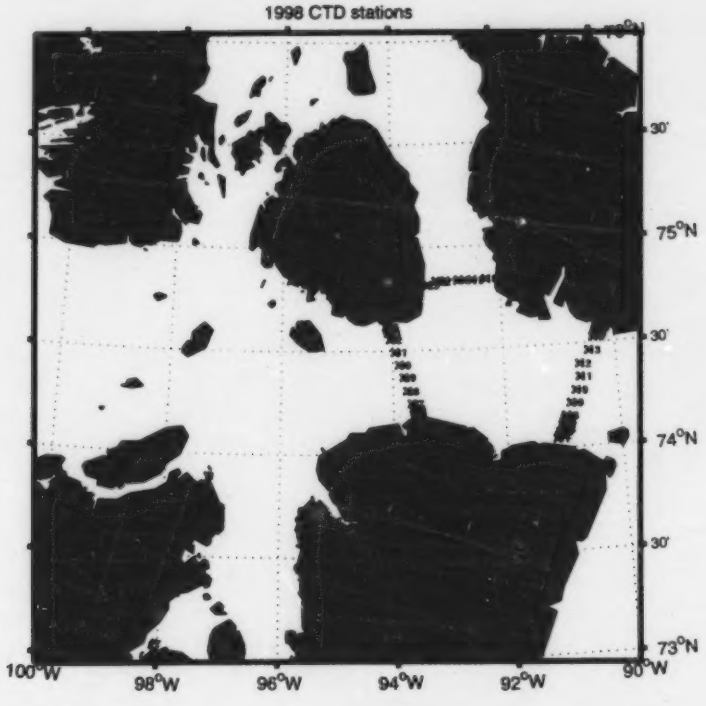

Figure 38 Map of CTD station locations for 1998 survey of Barrow Strait region.

6.2.1.1 West Barrow

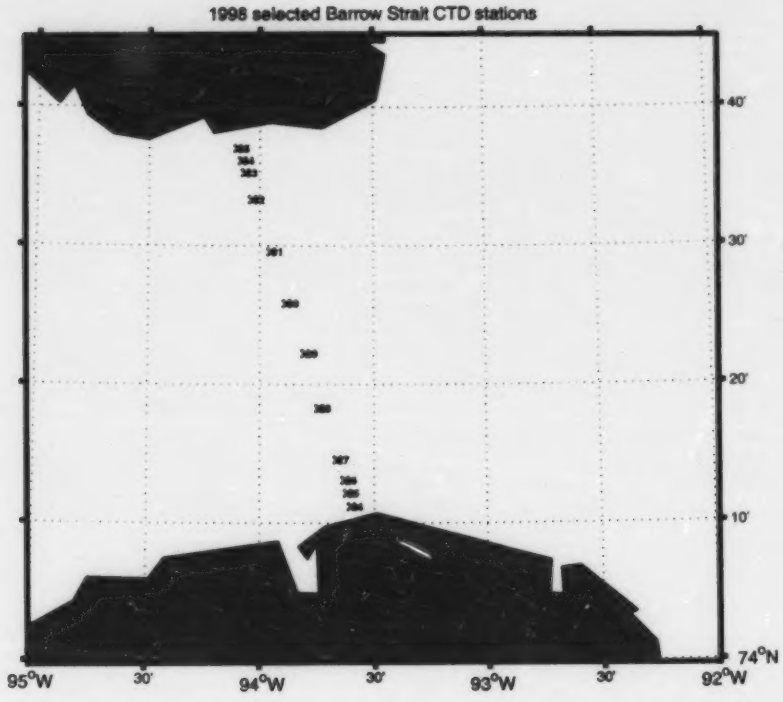

Figure 39 CTD stations used in geostrophic transport computations for west Barrow Strait in 1998.

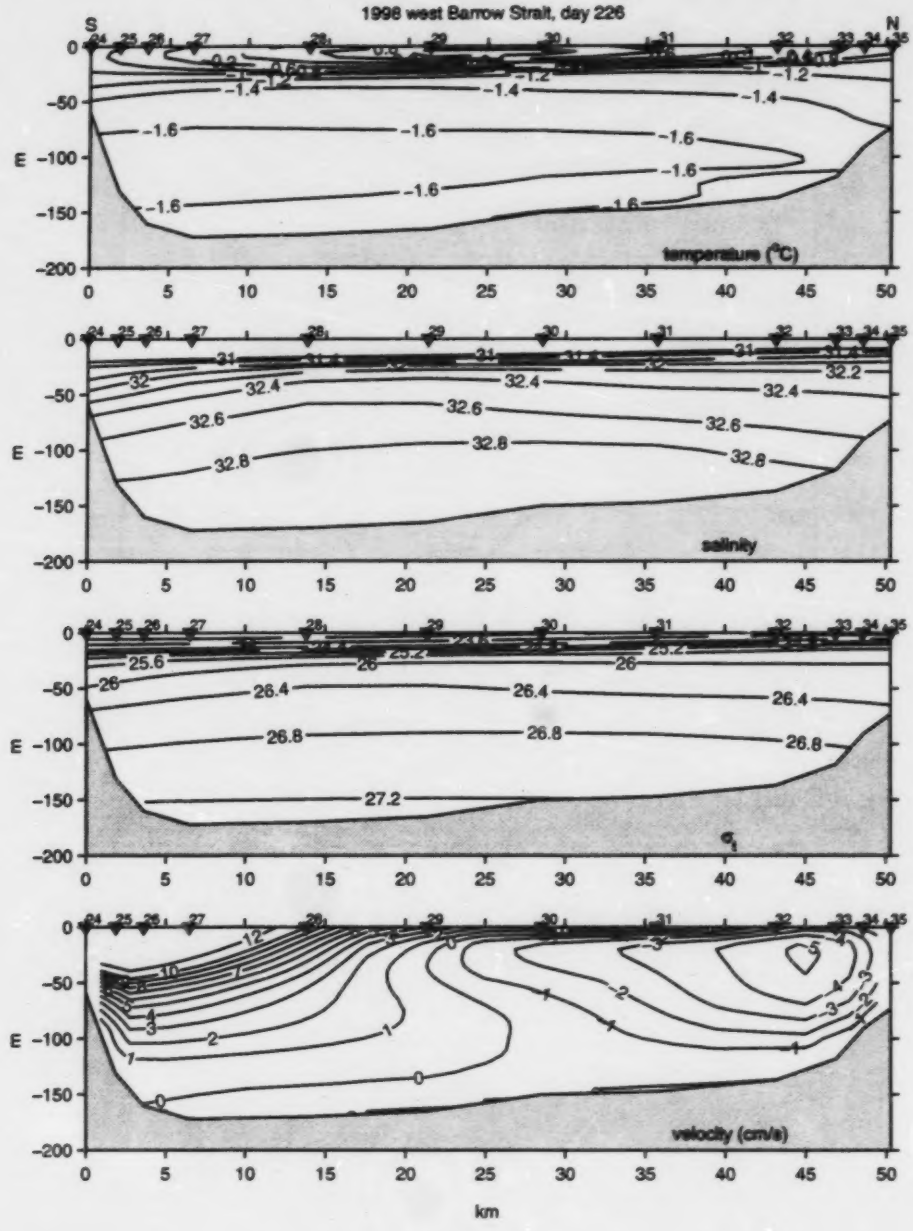

Figure 40 Cross-section of temperature, salinity, density, and relative velocity for 14 August 1998.

6.2.1.2 East Barrow

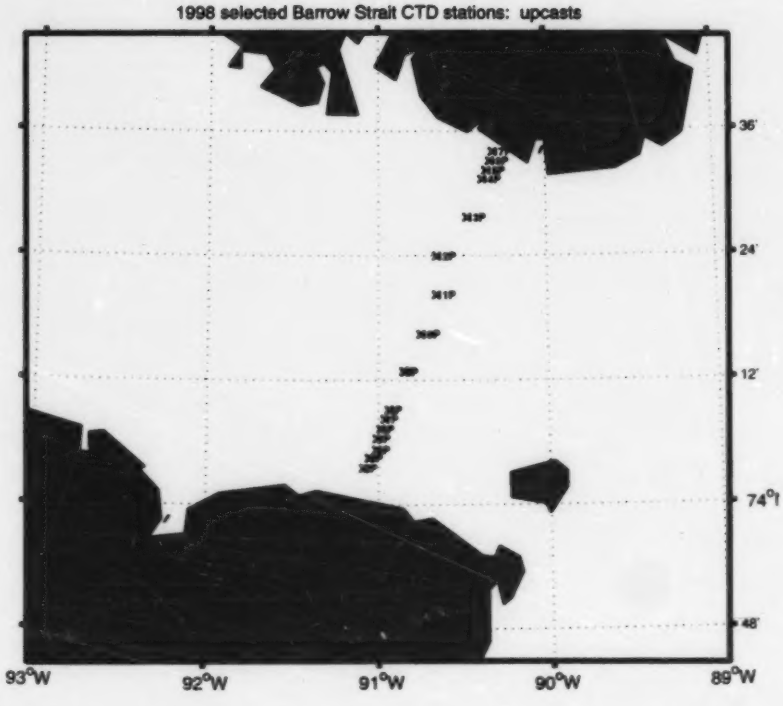

Figure 41 CTD stations used in geostrophic transport computations for east Barrow Strait in 1998.

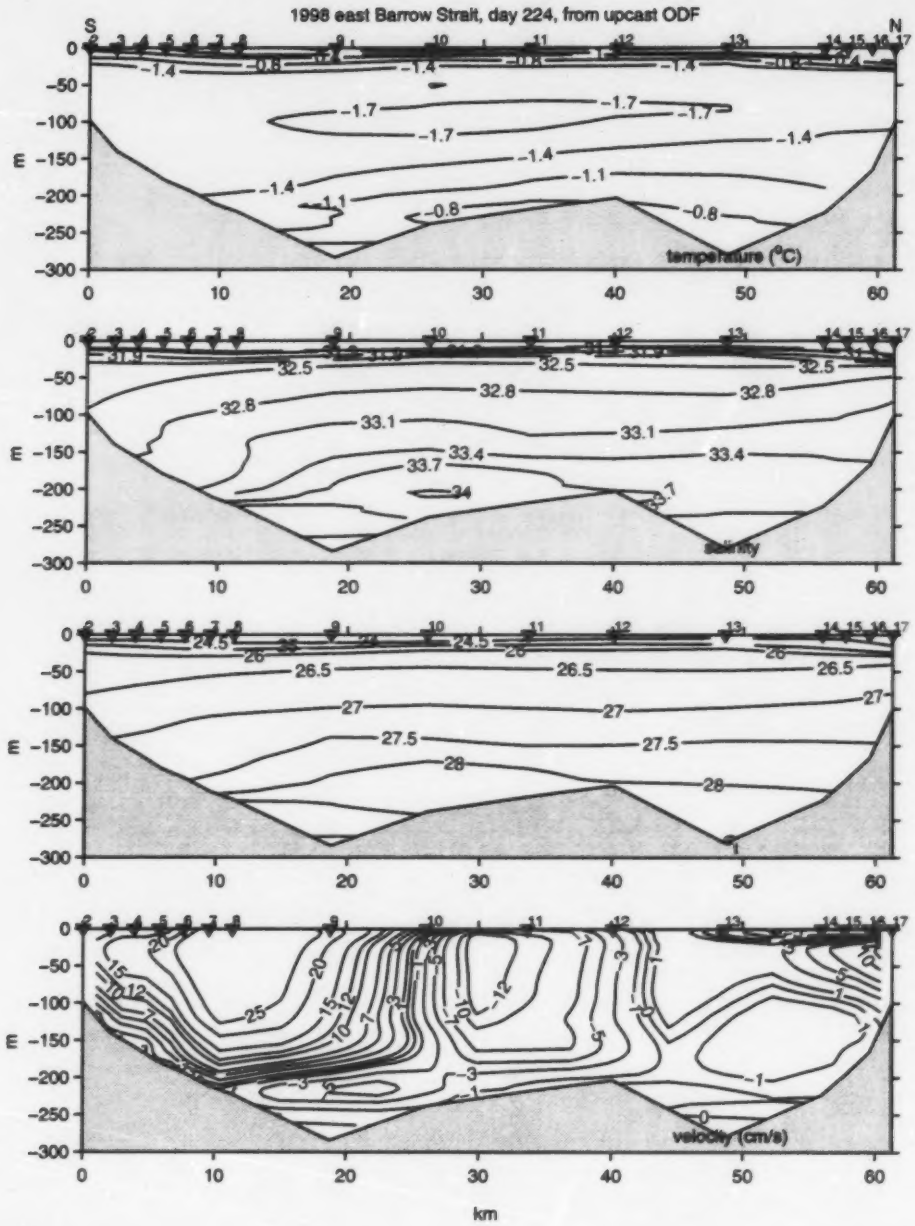

Figure 42 Cross-section of temperature, salinity, density, and relative velocity for 12 August 1998.

6.2.1.3 North Barrow

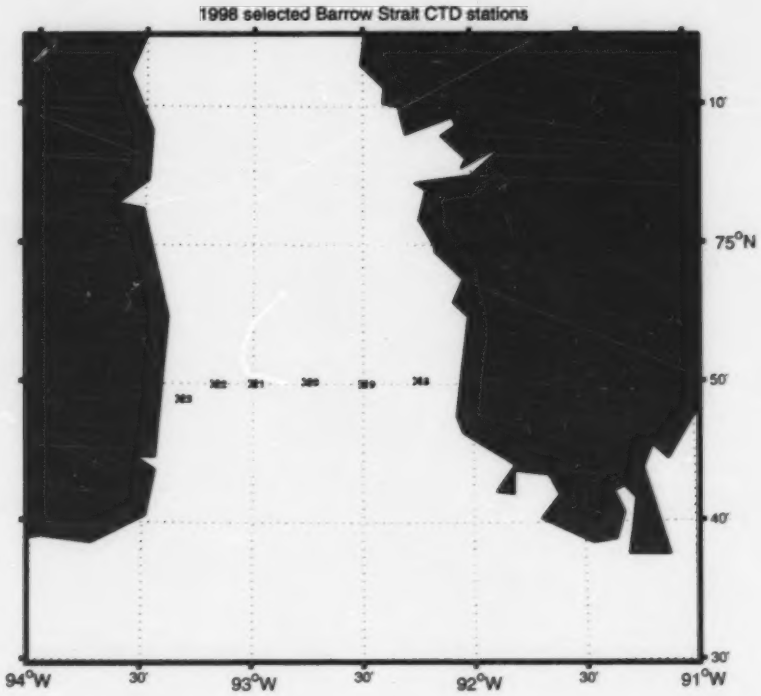

Figure 43 CTD stations used in geostrophic transport computations for north Barrow Strait in 1998.

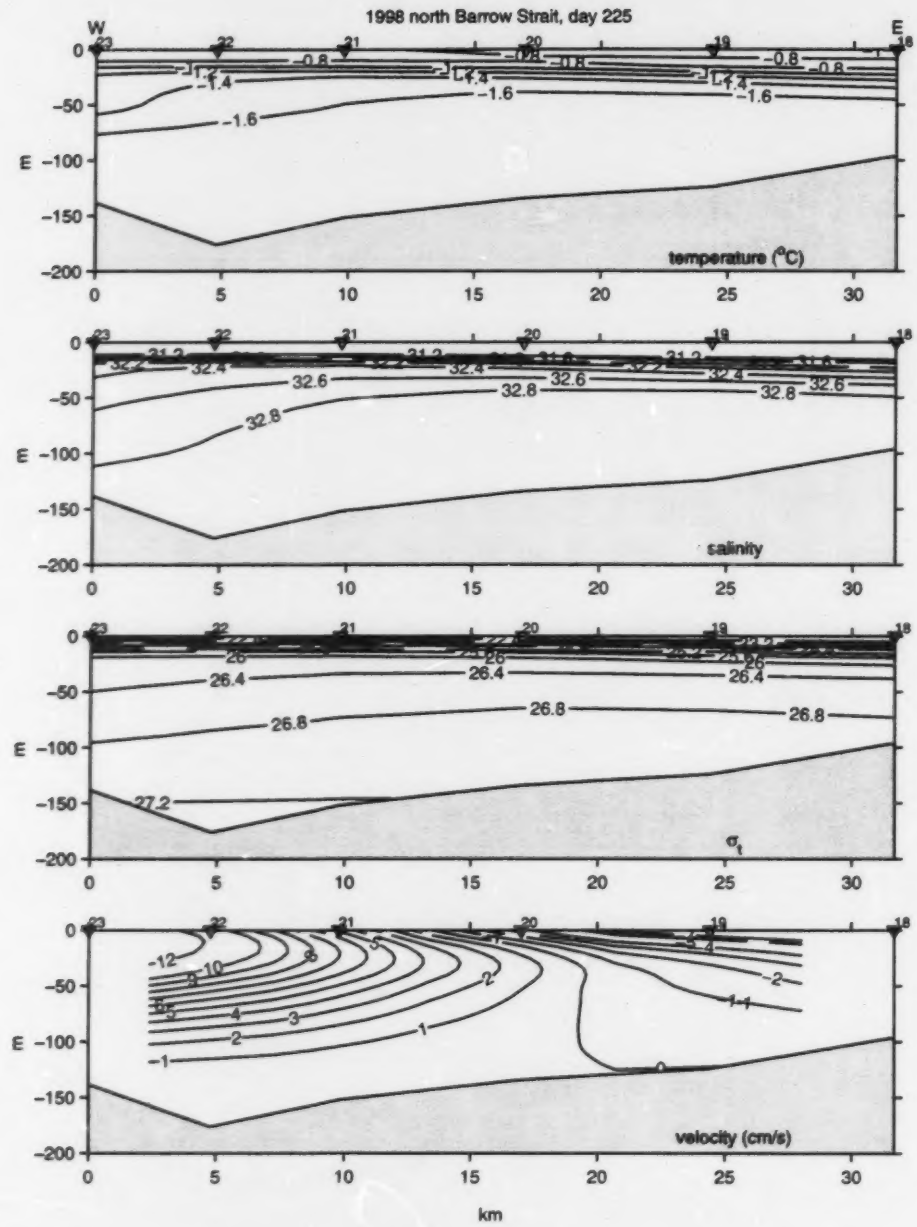

Figure 44 Cross-section of temperature, salinity, density, and relative velocity for 13 April 1998.

6.2.2 1999

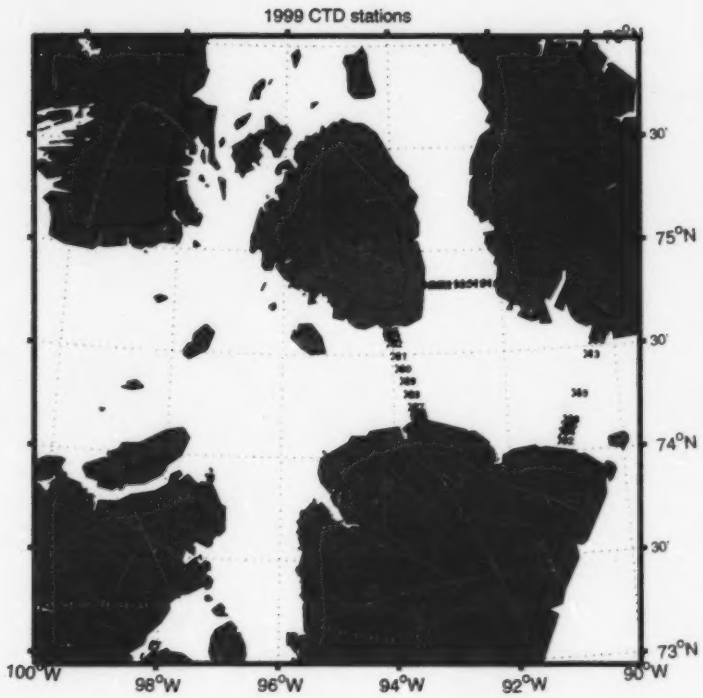

Figure 45 Map of CTD station locations for 1999 survey of Barrow Strait region.

6.2.2.1 West Barrow

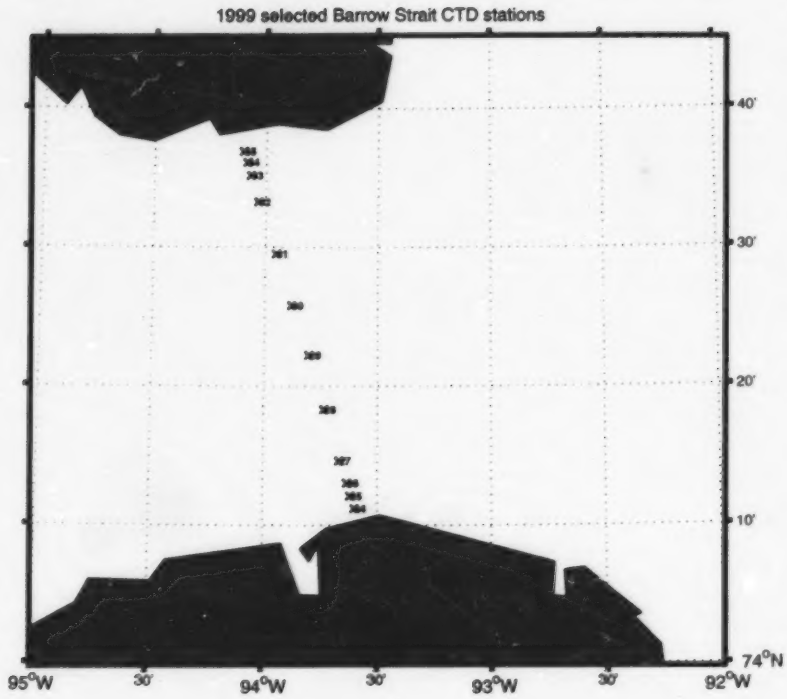

Figure 46 CTD stations used in geostrophic transport computations for west Barrow Strait in 1999.

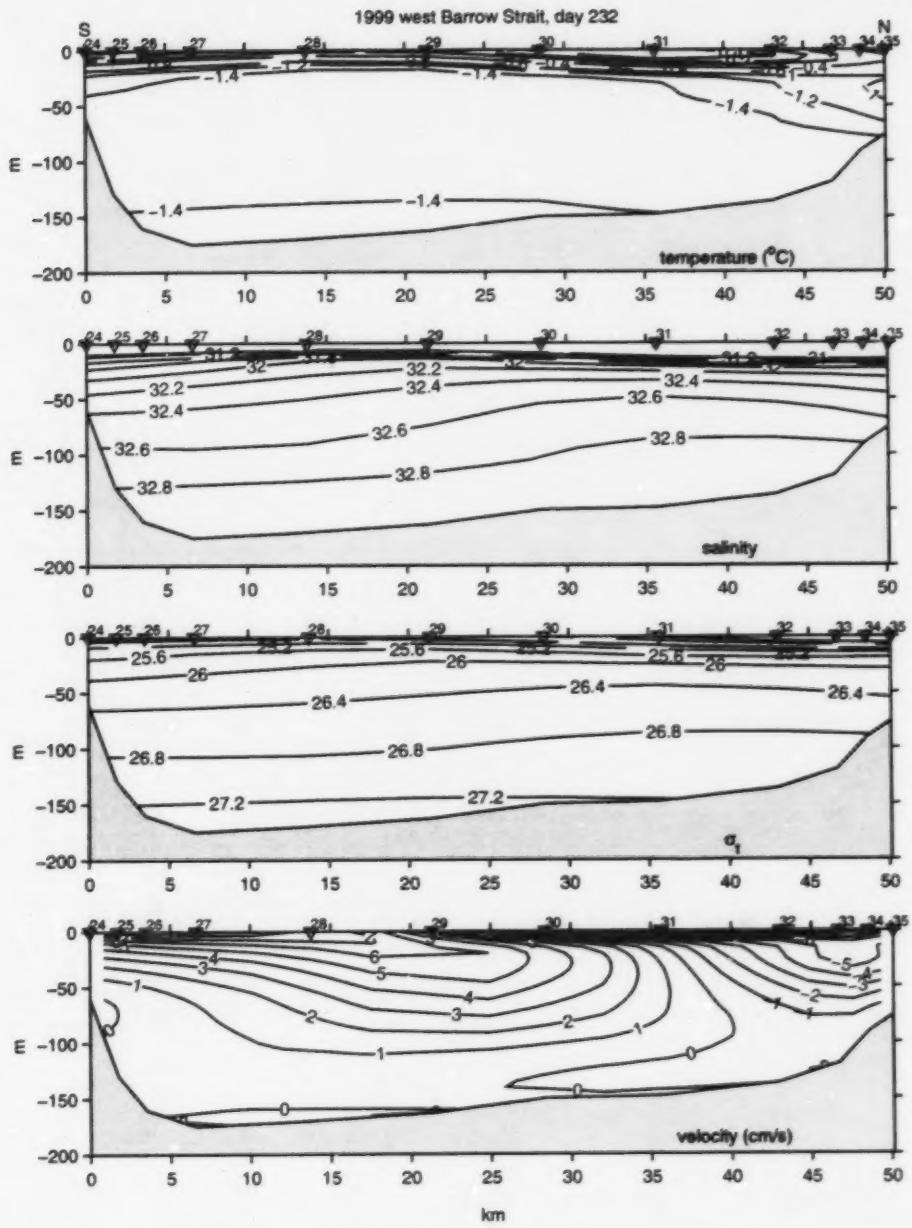

Figure 47 Cross-section of temperature, salinity, density, and relative velocity for 20 August 1999.

6.2.2.2 East Barrow

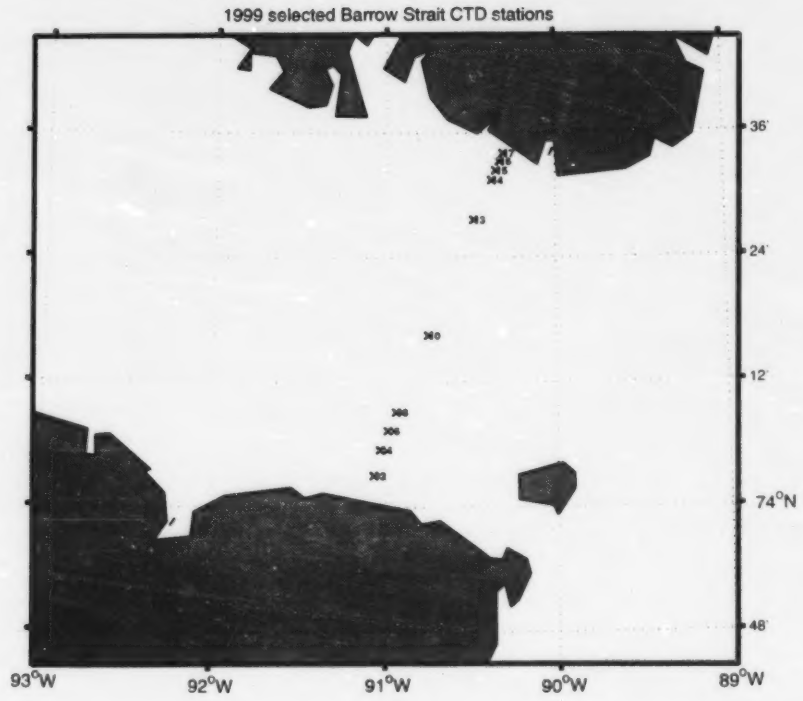

Figure 48 CTD stations used in geostrophic transport computations for east Barrow Strait in 1999.

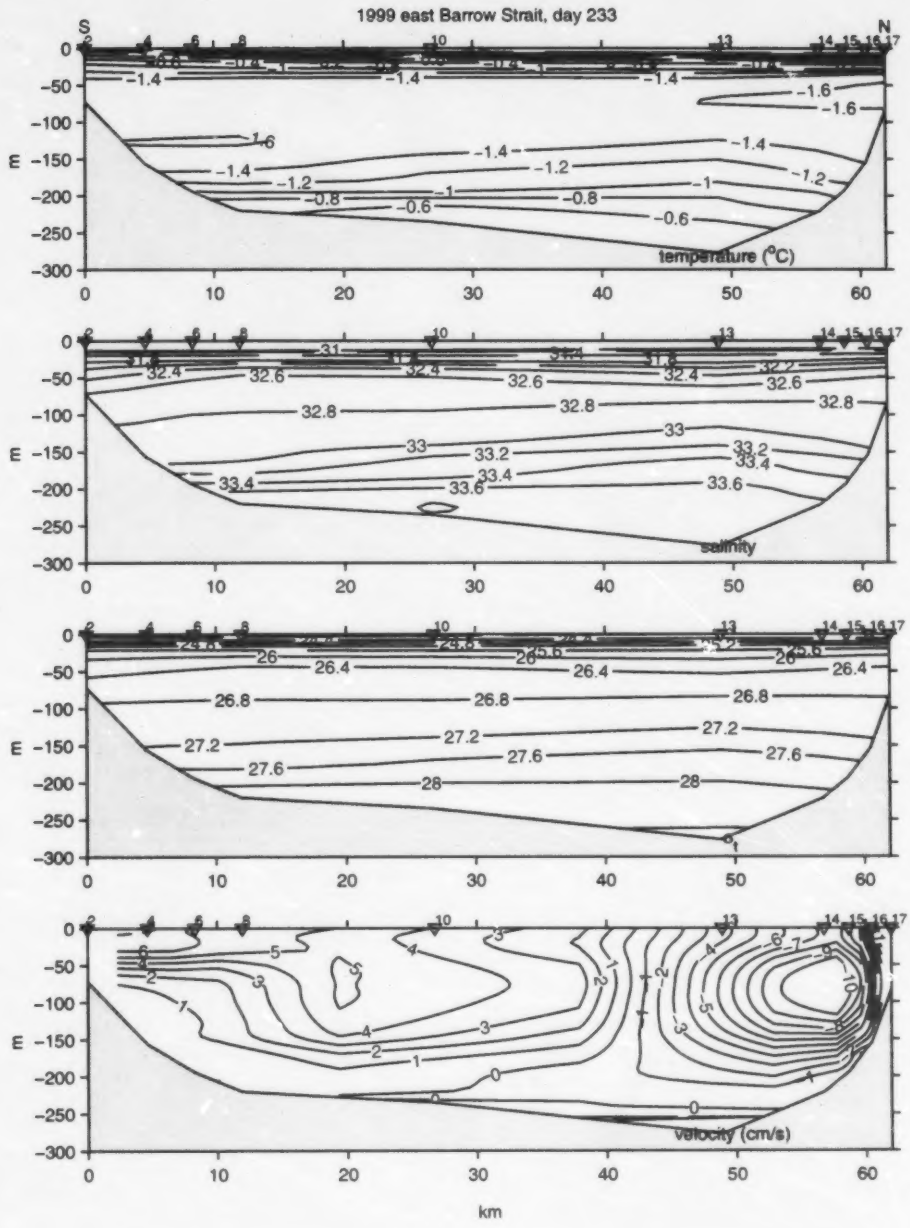

Figure 49 Cross-section of temperature, salinity, density, and relative velocity for 21 August 1999.

6.2.2.3 North Barrow

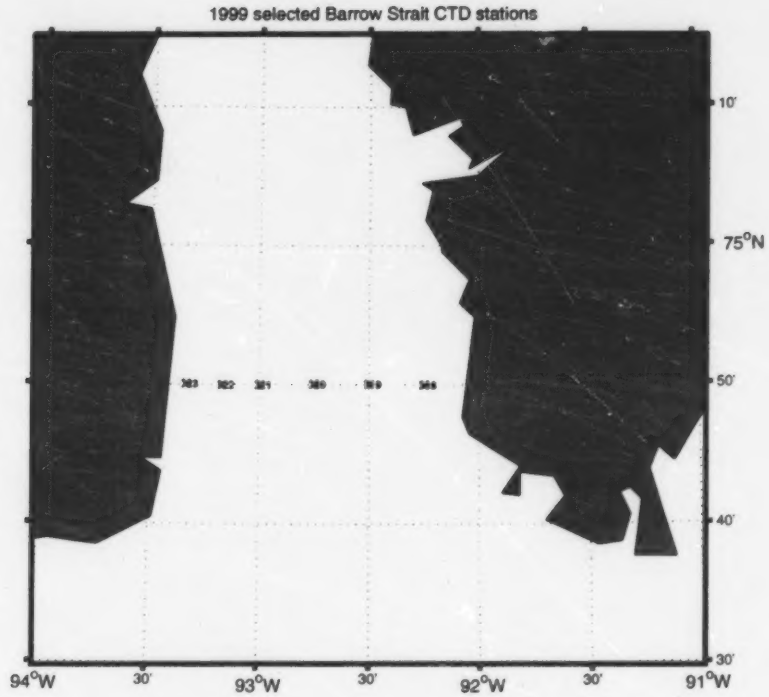

Figure 50 CTD stations used in geostrophic transport computations for north Barrow Strait in 1999.

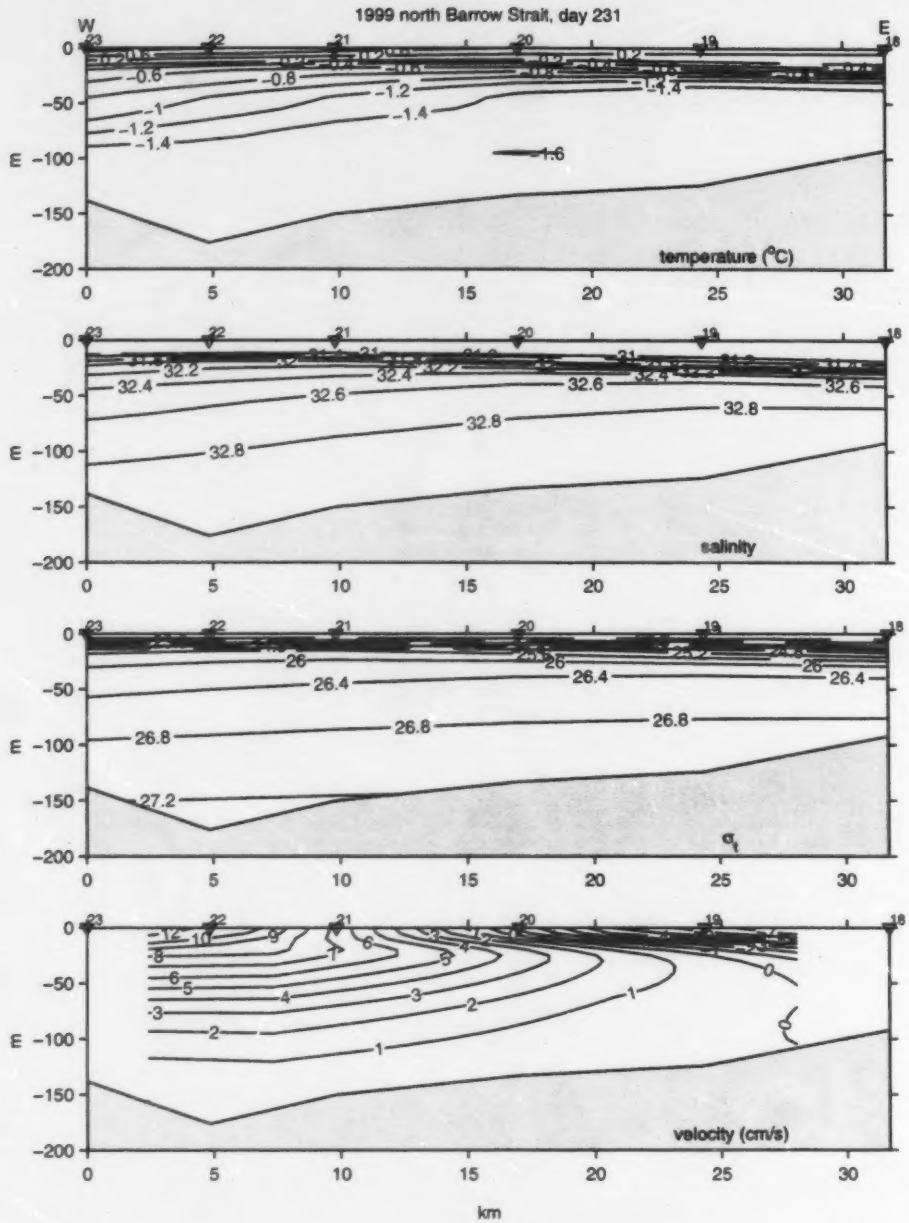

Figure 51 Cross-section of temperature, salinity, density, and relative velocity for 19 August 1999.

6.2.3 2000

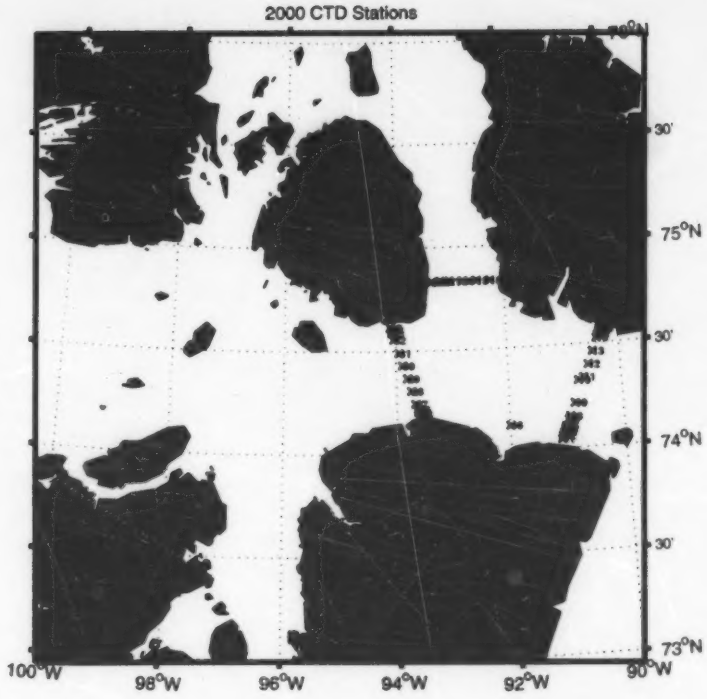

Figure 52 Map of CTD station locations for 2000 survey of Barrow Strait region.

6.2.3.1 West Barrow

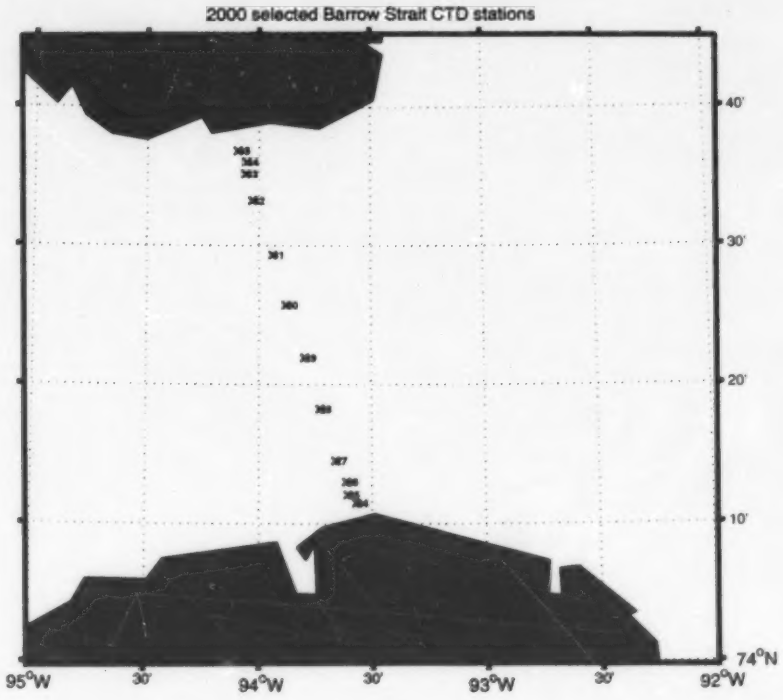

Figure 53 CTD stations used in geostrophic transport computations for west Barrow Strait in 2000.

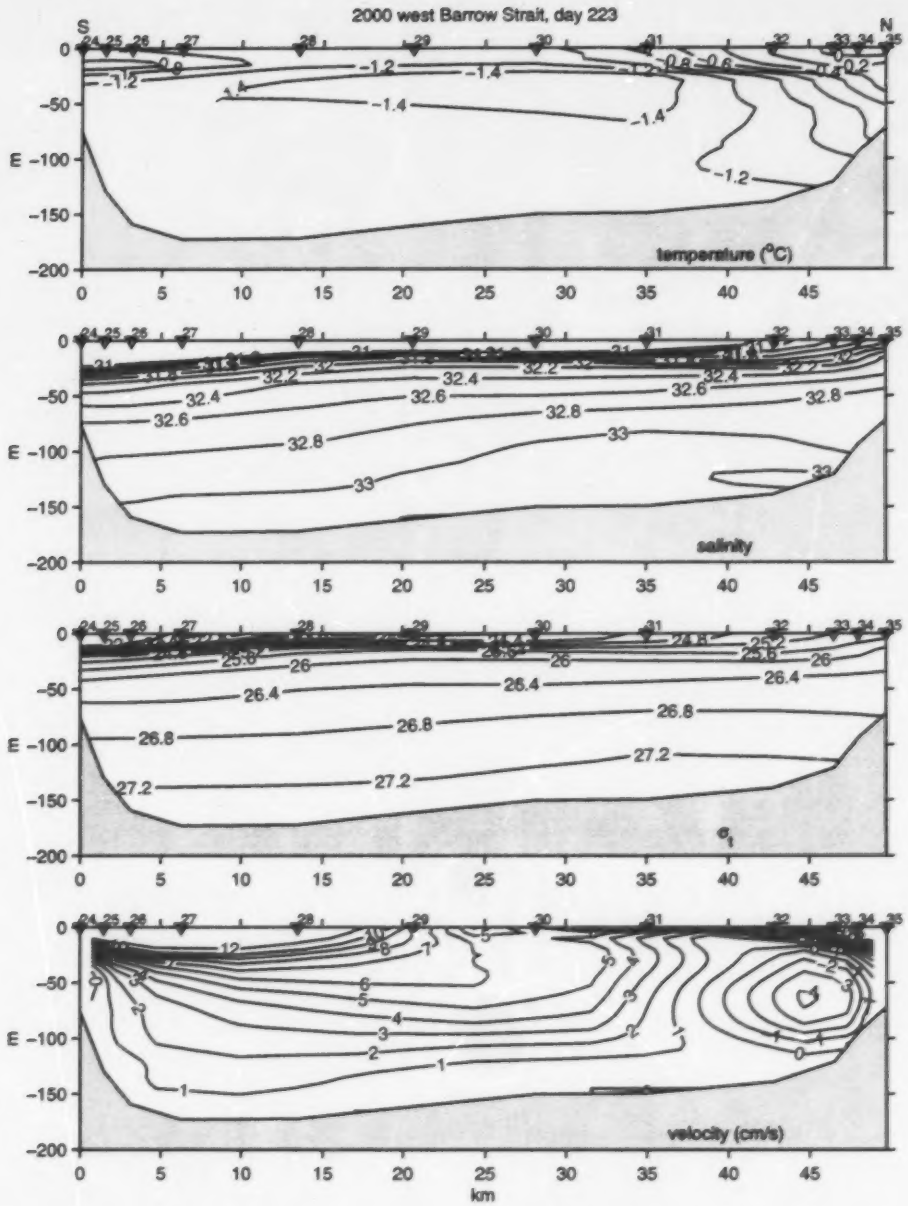

Figure 54 Cross-section of temperature, salinity, density, and relative velocity for 11 August 2000.

6.2.3.2 East Barrow

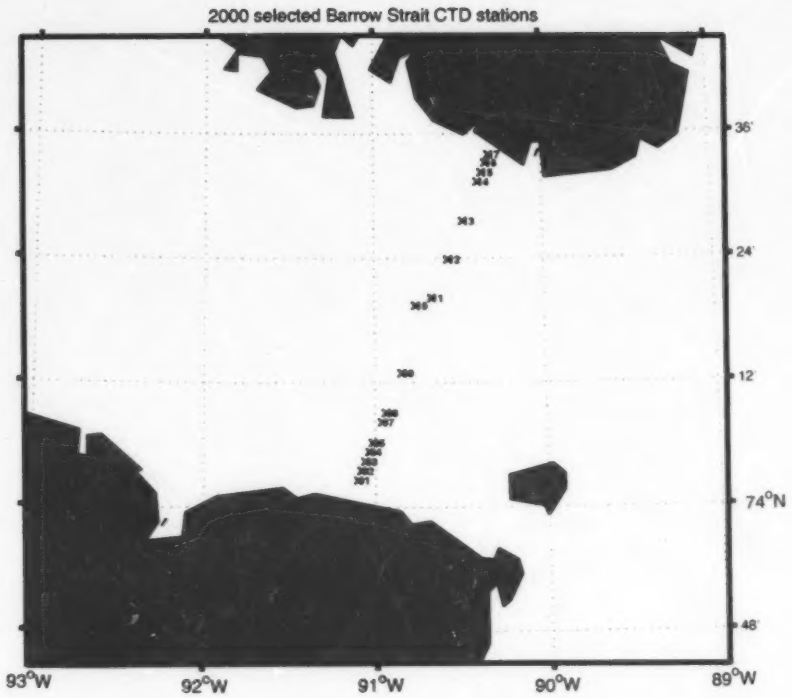

Figure 55 CTD stations used in geostrophic transport computations for east Barrow Strait in 2000.

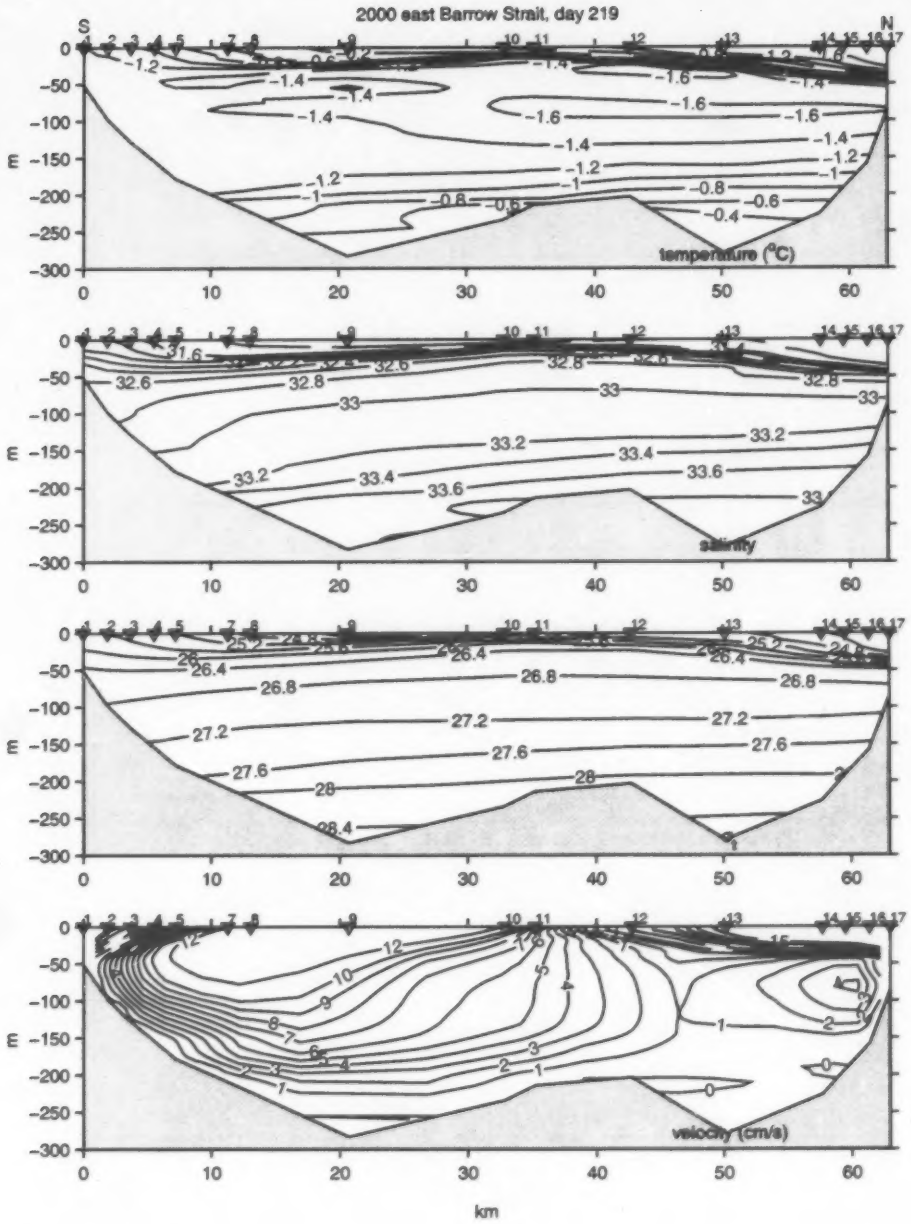

Figure 56 Cross-section of temperature, salinity, density, and relative velocity for 17 August 2000.

6.2.3.3 North Barrow

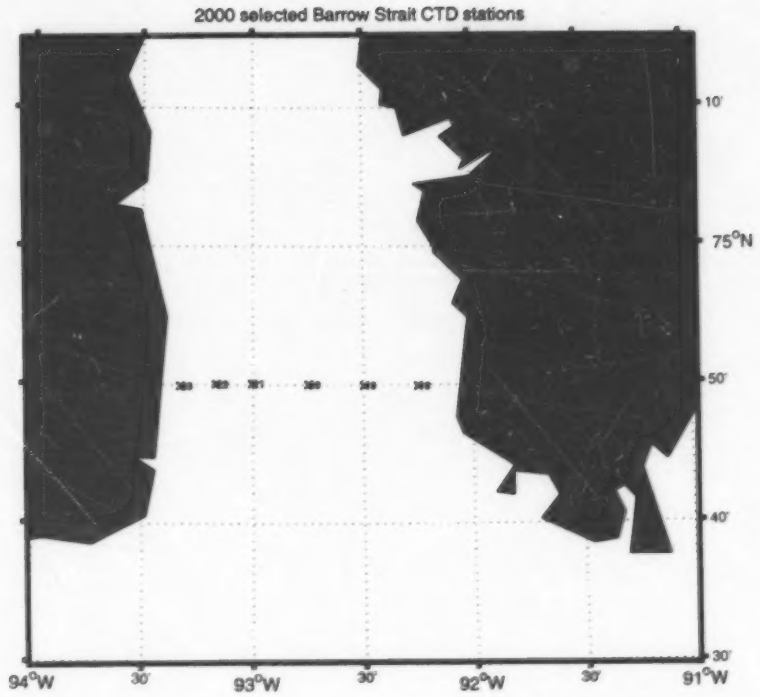

Figure 57 CTD stations used in geostrophic transport computations for north Barrow Strait in 2000.

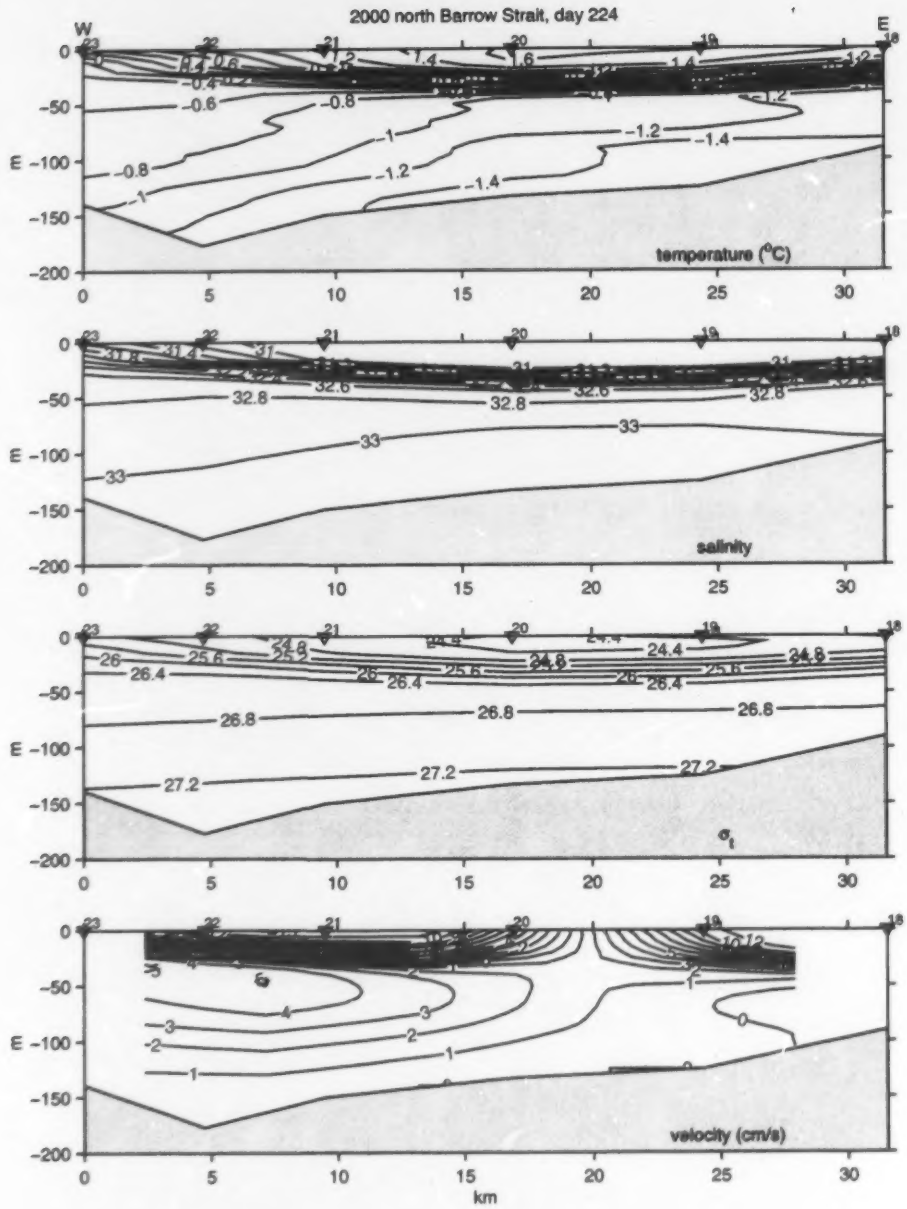

Figure 58 Cross-section of temperature, salinity, density, and relative velocity for 12 August 2000.